JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

Vol. 44 August, 1951 No. 4

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The Necessity for an Ecological Approach to Pest Control on Citrus in California[1,2]

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The development of the insecticidal control of pests on citrus in California has been a response to immediate and pressing problems. Possibly nowhere else in the world have such intensive efforts been directed toward control of pests of any given crop. Notable innovations and advances have been made in many phases of chemical pest control. The reasons for such development are obvious, since most of the pests of citrus in California have been introduced from other states or countries and it is to be expected that new pests will increase rapidly and hence must be controlled by any means possible.

Intensive pest control short of eradication of course seldom solves the problem. Insecticides must be reapplied at intervals. It has been observed in many cases that over the years the frequency of application of insecticides must be increased in order to maintain satisfactory control. This has been shown to be due to the development of genetic races resistant to insecticides and, in certain cases, to an adverse effect of insecticides on natural enemy populations. All this leads to more intensive use of insecticides. Treatment cannot be abandoned, because repeated experiences have shown that rapid pest increases follow cessation of treatment. This, at least, has been the general opinion of most observers and entomologists. And this brings us up to the present, with insecticidal pest control taken by many citrus growers as a matter of course, to be carried out at certain prescribed intervals. New insecticides have not as yet lessened the problem and many natural enemies to the observer appear to be ineffective. It seems to be time to take stock of our real progress.

In the past we have been too busy fighting the battle to take time out to look around and make plans for winning the war. Entomologists knew and still know that if our efforts to control pests chemically are relaxed the citrus crop generally suffers. Biological control through the introduction of natural enemies from other countries has been spectacularly successful in several instances, but the good which might be derived from natural enemies already established has been largely uninvestigated. Recently, however, there has been an opportunity to carry on some intensive ecological studies of citrus pest population dynamics without immediate regard to the control of any given pest. The possibilities now glimpsed offer much hope for future practical results.

UNTREATED GROVES.—It has long been known that parasites and predators attack nearly all the major and minor pests of citrus in California. But with certain important exceptions, these natural enemies have been considered to afford incidental help, only, not appreciable control. These evaluations, whether right or wrong, have been based upon observations fundamentally misleading, for nearly all knowledge of the effectiveness of entomophagous species has been acquired in groves receiving periodic insecticidal treatments.

Probably more than 99 per cent of the citrus acreage in California receives one or more applications of pest control materials or other materials each year. Under such conditions the maximum effectiveness of natural enemies can rarely if ever

[1] Paper presented as part of symposium on "Compatibility of Insecticide Programs with Biological Control" at the meeting of the American Association of Economic Entomologists at Denver, Colorado, Dec. 18–21, 1950.

[2] Paper No. 667, University of California Citrus Experiment Station, Riverside, California.

be attained. Much evidence, experimental as well as theoretical, is now available to support this postulate. That toxic materials may seriously affect certain natural enemy populations appears obvious; however, it seems just as evident that any material which seriously depresses the pest population will also seriously affect the population of its natural enemies. How then can entomologists hope to evaluate the true potential efficacy of natural enemies in the control of their host on citrus? The answer lies in untreated groves.

An untreated grove is not considered to be one in which pest control treatment has been skipped for one year or two. Indications are that three or four years may pass before a natural balance that has been upset is completely reattained. It is desirable, therefore, to restrict basic studies of this type as much as possible to groves that have received virtually no insecticidal, fungicidal, or deficiency treatments for five or more years. Such groves in California, with the exception of abandoned ones, are extremely rare. They occur only as a result of a very fortunate combination of circumstances which have, in nearly all cases studied, resulted in a commercially satisfactory natural balance between pests and their enemies. In the past, conditions in such unique groves have frequently been explained away as due, not to natural enemies, but to other factors such as resistant trees or locally extreme weather conditions. Prior to 1948, to the author's knowledge, no detailed ecological studies were ever carried out in California citrus groves untreated for long periods. Since that time such studies have shown that certain natural enemies which were thought to be ineffective are potentially effective in control of their host, and that certain factors which are adverse to natural enemies may be modified to enhance biological control.

MEASUREMENT OF EFFECTIVENESS OF NATURAL ENEMIES.—Experimental methods of evaluating the effectiveness of natural enemies have been extremely important in supplementing quantitative population data and in providing proof that parasites and/or predators actually are the factors responsible for natural control. These include the sleeve check method (Smith & DeBach 1942; DeBach, Dietrick & Fleschner 1949), the insecticidal check method (DeBach 1946), and the biological check method (manuscript in preparation for publication). All these methods supplement one another but employ the same principle; that is, they eliminate or inhibit natural enemies on certain field units and permit comparison with other units having unimpeded natural enemy activity. The biological check method employs ants to reduce natural enemy populations.

These methods have made it possible to obtain positive data in certain untreated groves which prove that unaided natural control of several major citrus pests, generally thought to have ineffective natural enemies, may occur. This includes control of the California red scale, *Aonidiella aurantii* (Mask.), by *Aphytis chrysomphali* (Mercet) (DeBach, Fleschner & Dietrick 1950); control of the citrus red mite, *Paratetranychus citri* (McG.), by several predatory species (DeBach, Fleschner & Dietrick 1951); and control of the yellow scale, *Aonidiella citrina* (Coq.), by *Comperiella bifasciata* How. and *Aphytis* spp. (Flanders 1945 and DeBach's unpublished data). Other potential pests whose natural enemies generally have been deemed more important, and which, in general, are under very satisfactory natural control in these untreated groves, include the black scale, *Saissetia oleae* (Bern.); the citrus mealybug, *Pseudococcus citri* (Risso); the soft brown scale, *Coccus hesperidum* L.; the cottony-cushion scale, *Icerya purchasi* Mask., and several species of citrus aphids.

The obvious reason for certain groves going untreated for periods of 10 to 24 years lies in the fact that they have posed practically no major pest problems. Had any pest become severe enough, such groves would have been treated. This does not mean that all citrus pests in California have potentially highly effective natural enemies; not all pests are present in all citrus areas or injurious on all citrus varieties. Certain citrus-feeding insects such as the purple scale, *Lepidosaphes beckii* (Newm.), the citrus thrips, *Scirtothrips citri* (Moult.), and the citrus bud mite, *Aceria sheldoni* (Ewing), do not have obviously effective natural enemies, but they have been little studied as yet. Field ecological studies, in fact, are in their infancy, but the promise they show

justifies considerable intensification of effort.

Extension of Natural Control.—The possibilities of extending natural control into groves now receiving periodic insecticidal treatments are encouraging but at present largely untried. It appears logical to believe that local extension of natural control could occur in areas adjacent to untreated groves now controlled biologically. How far this idea can be carried depends upon further acquisition of basic ecological information.

Knowledge already obtained concerning certain factors adverse to natural enemies indicates that such factors may offer serious limitations to obtaining more general natural control unless they can be modified. We already know that various environmental factors may at times operate against natural enemies. Some of these include (1) a periodic lack of suitable host stages for parasites, (2) a periodic scarcity of hosts for general predators, (3) the occurrence of unfavorable meteorological conditions, (4) the adverse activity of ants, (5) the adverse effects of dust originating from the soil, and (6) the adverse effects of insecticidal and other chemical applications. Certain means of alleviating the adversity of these factors appear to offer promise. Others will undoubtedly be disclosed by further work.

Synchronization of Host and Parasite.—A periodic lack of host stages suitable for parasitism (asynchronization) may be overcome by (1) periodic field colonization of parasites at critical periods, (2) inoculation of citrus trees with the host insect in order to obtain a continuity of susceptible host stages, and (3) the use of alternate host plants to maintain a continuity of susceptible host stages.

Periodic colonization of *Aphytis* spp. resulting in control of the California red scale has been demonstrated by DeBach *et al.* (1950) in certain experimental plots. A related technique is employed commercially in southern California with *Metaphycus helvolus* (Comp.) for the control of black scale (Flanders 1949). Interesting possibilities for inoculation of citrus trees with the host, in this case the black scale, in order to maintain continuity of host stages susceptible to parasitism by *M. helvolus*, have been brought out by Smith & DeBach (1950). The use of the oleander as an alternate host plant for the maintenance of populations of *M. helvolus* in the field during periods of scarcity has been developed by Flanders (1949).

Maintenance of Hosts for General Predators.—General predators may act as a sort of balance wheel in the pest-natural enemy complex. They tend to feed on whatever pest is present in abundance. Although in themselves perhaps incapable of causing natural control below economic levels, they slow down the rate of increase of potential pests or reduce peak infestations when specific natural enemies have perhaps been reduced by other factors. If general predators are to do the most good, they must have a continuity of food available. This may not be practicable on the citrus tree itself, but the use of prey-infested cover crops could be the answer to an appreciably higher average of the general predator population. The desirability of using summer or permanent cover crops would of course have to be investigated with respect to the effects on general citrus culture.

Modification of Meteorological Conditions.—The occurrence of unfavorable meteorological conditions relates principally to high temperature-low humidity combinations and to low temperatures. The possibility of modifying these factors is limited, although humidity may be modified to a certain extent by the use of cover crops and sprinkler-type irrigation. The encouragement of citrus trees to produce dense foliage may be an important procedure.

Ant Control.—The adverse effects of ants on pest populations is well known. Newell & Barber (1913) in their early work with the Argentine ant in Louisiana noted severe increases in populations of mealybugs and of unarmored and armored scales in relation to ant infestations. In the untreated groves which we have studied, much quantitative information has been obtained on the effect of ants on natural enemies. They attack nearly all natural enemies; if they cannot seize them, they constantly disturb them. Parasitization of the California red scale by *Aphytis* is considerably reduced on ant-infested trees; likewise, populations of predators of this scale are sharply reduced. Flanders (1945) showed that parasitization of the yellow scale, *Aonidiella citrina* (Coq.) by *Comperiella bifasciata*

How. was reduced on ant-infested trees. In the presence of effective natural enemies, ant control makes the difference between success and failure of natural control. Ant control can be obtained, of course, by the use of poison baits, sprays or dusts.

Soil Dust Control.—The effects of road and grove dust have been observed in the field for many years. Diaspine scales and spider mites, in particular, frequently show marked population increases on dusty trees. Several explanations have been put forth to account for this, including increased favorability of the substratum with respect to clinging of scale crawlers and mites on the leaf, and an adverse effect of the dust on natural enemies. There does not appear to be any quantitative data in the literature regarding these factors. However, R. C. Dickson and D. L. Lindgren (unpublished data) of the Division of Entomology of the University of California at Riverside, have found in laboratory studies that road dust reduces rather than increases the percentage of California red scale crawlers which settle.

The author and his colleagues have found in current laboratory and field studies that the California red scale parasite *Aphytis chrysomphali* (Mercet) parasitizes a much lower percentage of scales on dusty surfaces than on clean surfaces. Clean trees therefore seem to be very important from the standpoint of biological control. Dust-control possibilities exist in the form of overhead sprinklers for irrigation, permanent cover crops, reduction in soil discing, and dust-reducing surfaces for field roads.

Coordination of Chemical and Biological Control.—The adverse effects of insecticides and other materials against natural enemies have been strikingly emphasized in recent years by the use of DDT and other new organic chemicals used in pest control. This is now such common knowledge that it would seem superfluous to discuss it in detail. In California, on citrus, DDT applications have resulted in increases in the cottony-cushion scale, the citrus red mite, the citrus mealybug and other mealybugs, the California red scale, the yellow scale, the orange tortrix, and several species of aphids. DeBach & Bartlett (1951) have shown for each pest species studied in detail that these increases are correlated with decreases in natural enemy populations. Other materials not so toxic and having shorter-term residual effect than DDT may nevertheless seriously upset the natural balance, especially when reapplied periodically, as many are on citrus. DeBach (1949) and DeBach & Bartlett (1951) have shown that even certain so-called inert materials, such as talc, may reduce natural enemy populations. Zinc-sulfate and cryolite were shown to reduce populations of citrus red mite predators. Sulfur is known to have upset black scale and citrus mealybug populations through effects on natural enemies.

The starvation of natural enemies following drastic reduction in host populations by insecticidal applications can be fully as serious as effects from direct toxicity of insecticides to natural enemies. For many reasons too detailed for inclusion here it would be virtually impossible for most natural enemies to secure or maintain a satisfactory balance with a host which is periodically nearly exterminated by an insecticide.

The foregoing statements should not lead to the conclusion that insecticides are not, and will not continue for many years to be, essential to successful control of certain citrus pests. A complementary, mutually compatible program of chemical and biological control is the immediate objective. In its insecticide research program the Division of Entomology at Riverside has recognized, in addition to the influence of insecticides on natural enemies, the paucity of sound ecological information regarding the insecticide and the pest alone. Steps are being taken to acquire such basic information.

As ecological studies in untreated groves indicate which pests may be controlled biologically, and if it develops that this control can be extended into other groves, then the insecticides necessary against those pests not having efficient natural enemies must be chosen on the basis of their over-all effect against the pest and all natural enemies—not the pest alone. This could mean, for instance, the use of an insecticide considerably less effective than the best one known for control of a given pest, but one which would have much less effect on the other species involved than would the better insecticide. This field has scarcely been touched and only by basic ecological studies can it be exploited successfully.

Summary.—Insecticidal treatments for citrus pests have developed as emergency measures in response to immediate problems. Although such treatments have made it possible to raise commercial citrus crops, this immediate need has led to the neglect of fundamental studies of natural factors affecting pest populations. In many cases such treatments have resulted in no final solutions to pest problems; rather, repeated applications have been necessary in order to maintain control. Such repetition of treatment may indeed serve in time to intensify the problem. Such a result may occur through (1) the development of genetic races of a pest resistant to the insecticide used, and (2) the reduction of natural enemy populations by the insecticide used. The emergency thus becomes self-perpetuating.

Parasites and predators, in so far as they are density-dependent factors, are capable of attaining and maintaining satisfactory pest control under certain conditions. Natural enemies, in general, cannot demonstrate their true potential in groves receiving periodic insecticidal treatments. Treated groves, however, comprise at least 99 per cent of the citrus acreage; hence most ideas concerning the effectiveness of natural enemies have been acquired in treated groves. The real effectiveness of natural enemies already established on citrus pests can be demonstrated only by thorough ecological studies in untreated groves. Studies in several such untreated groves have shown that biological control may be effective on certain major citrus pests ordinarily thought of as not having efficient natural enemies. This includes, principally, the California red scale, the citrus red mite, and the yellow scale in Tulare and Ventura counties. Certain other pests remain to be investigated.

Continued studies in untreated groves of the biotic and abiotic ecological factors affecting pest populations, and of the same type of factors affecting natural enemy populations, offer promise of extending biological control into groves now receiving chemical pest control treatments. A knowledge of the adverse ecological factors affecting natural enemies may lead to methods of environmental modification which will alleviate these difficulties. Some possibilities for environmental manipulation include the following: colonization of natural enemies at critical periods; control of ants and grove dust, both of which are detrimental to natural enemies; artificial infestation of the plant with the pest insect in order to synchronize development of host and natural enemies; use of cover crops to reduce dust, maintain humidity during dry periods, and act as a reservoir for general predators; the use of alternate host plants to maintain more constant populations of the host and specific natural enemies; and the use of necessary insecticides least harmful to the natural enemy complex.

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Selective Insecticides and Biological Control

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A number of investigators have shown that the modern conventional insecticides, when directed against pests, lead in due course to two important and undesirable phenomena. The first is a rapid re-infestation of the treated crop despite satisfactory initial mortality—a phenomenon well explained by Volterra's *Law of the Disturbance of Averages*, according to which the partial destruction of pests and beneficial insects results in an increase in the proportion of pests to beneficial insects. Thus, under these conditions, to maintain control of the pest a much greater frequency of spray treatment is required.

The second undesirable phenomenon is the segregation of strains of pests resistant to the insecticide used. This is thought to arise in the following way. The nonresistant individuals in the pest population are destroyed by the insecticide and only the resistant individuals remain. Resistance has, in several cases, been shown to be a recessive gene, and if the offspring is again sprayed and only the resistant specimens survive, a strain of insects resistant to the insecticide is brought into being. The literature on this subject has been well summarised by H. S. Smith (1941) and H. J. Quayle (1943), and the challenging teaching of these investigators has stimulated many of us to consider what remedies are possible for this undesirable sequence of chemical pest control.

As a remedy for the prevention of the segregation of resistant strains, frequent variation of the insecticides has been suggested, the assumption being that survivors of one insecticide treatment will be killed by a subsequent application of an alternative insecticide with a very different mode of toxic action.

Biological methods to prevent the increase of the pest population after spray treatment—and the consequent need for greater frequency of spray treatment—have been suggested by Marchal (1908) Vuilet A (1914), Flanders (1949), apart from increasing the tenacity of insecticides—a method which has severe limitations owing to the toxic residue problem on foodstuffs which the greater tenacity of insecticides produces.

In 1944, and again in 1949 and 1950, we put forward the working hypotheses that the remedy for both the undesirable phenomena lies in the supplementation of biological control with chemical control by using selective insecticides. "Selective insecticides" we define as insecticides toxic to the pests but not toxic to the beneficial insects. After an application of such an insecticide, the beneficial insects which survive the spray treatment exert two distinct effects on such fraction of the pest population as survives.

1) An immediate effect—the unharmed beneficial insects mop up the surviving individuals of the pest population and thus increase the apparent effectiveness of the insecticide application. This was shown by Morrill (1921), Frogatt (1905), Grosswald (1934), Noble (1935), Clausen (1936), and Woglum (1947).

2) A delayed effect—the unharmed beneficials or their progeny act on the surviving pest population and prevent the start of the rapid build-up of the pest population which is so often observed when conventional insecticides are used. Thus the intervals between chemical treatments are prolonged.

It must be pointed out that the effectiveness of an insecticide selective either by its nature or through a judicious choice of the right concentration and application technique should be such as to allow the survival of sufficient individuals of the pest population to maintain an effective population density of natural enemies. This requirement can be deduced from the work of Boyce (1936) and Flanders (1940) who have shown that a selective insecticide if applied widely, frequently and thoroughly enough, may have a very destructive indirect effect through starvation of specific natural enemies. Should the application of selective insecticides become widespread, those parasites and predators which work on pests at low population density levels will become the most effective beneficials.

Early Experiments.—During recent

[1] Presented as a part of "Biological Control Symposium" in Denver, December, 1950.

years we have examined many insecticides for their selectivity and among many failures we have had some successes.

The first selective insecticide which we examined was nicotine vapour against aphids. It was shown in 1944 that nicotine vapour will kill aphids when exposed for 60 seconds under a drag sheet with the nicotine vapour applied as an aerosol at the rate of 1.5 to 2.5 lb. of nicotine per acre.

By counting the population of aphids and the predators, syrphids and the Braconid parasite *Aphidius brassicae*, it was shown that, after a high mortality of the the pests effected by the nicotine vapour, a low level of the pest population is maintained by the population of predators and and parasites which is not affected by the treatment. It was further shown that, following the considerable reduction of their food supply by the insecticide and their own feeding, the beneficial insects disperse and therefore the population of these beneficial insects cannot be relied upon to keep fields free from newly immigrating aphids for longer than about 4 weeks (Ripper, 1944).

We have tried to produce a selectivity by coating stomach poisons with substances which are only digestible in the digestive tracts of phytophagous insects, relying for its effect on the differences between the enzymatic apparatus of the digestive tracts in the phytophagous insects and the carnivorous or pollinating insects. By the coating of DDT particles with various hemicelluloses, we were able to produce an insecticide, best described as a mass of micro-pills, which did not poison any insect other than the phytophagous insect possessing a hemicellulase.

There are practical difficulties to the application of this method and the preparations are necessarily costly (Ripper *et al.* 1948). We have therefore abandoned this approach and, after Greenslade in our research laboratories discovered that octamethylphosphoramide is a selective aphicide, we concentrated our selective insecticide research on systemic insecticides (Greenslade 1948; Ripper *et al.* 1949, Ripper *et al.* 1950).

We define as systemic insecticides those which are taken up by the sap stream of the plant and, to some extent, translocated in the plant. It is possible to procure quick absorption of such a chemical by the plant so that the insecticide is no longer available to any insect other than plant-feeding or plant-sucking insects.

INSECTICIDAL ACTION AND SELECTIVE TOXICITY OF SYSTEMIC INSECTICIDE.—The best explored systemic insecticide is octamethyl pyrophosphoramide.[1]

We have tested "*OMPA*" on a great number of aphids, thrips, whiteflies, leaf hoppers, red spider mites, etc., and found it effective in killing all active stages of aphids and red spiders. We have sprayed apples, pears, cherries, plums, peaches, hops, strawberries, raspberries, blackberries, loganberries, Brassicae, cucurbits, peas and beans, all varieties of beets, carrots and citrus, and in concentrations which killed the aphids we found no phytocidal effect on hops, Brassicae, cucurbits, strawberries, raspberries, loganberries, blackberries, peas and beans, beets, carrots and citrus.

In all the following experiments where plants had been sprayed with systemics we exposed pests and predators at frequent intervals after spray treatment and counted the mortality obtained. While results show that the systemics used *gave a good mortality of aphids, significant differences appeared in their effects on beneficials.*

When spraying aphis-eating ladybirds with concentrations which eliminate the aphids, no effect whatsoever on ladybirds at any stage is observed (Tables 1 and 2). We have fed ladybirds with aphids which were killed by *Schradan* and found them totally unaffected.

The systemic insecticides *C.R. 409* or *Isopestox* however behave differently in their effect on pests and predators. *Schradan* causes no, or, at worst, a low mortality of beneficials, *but C.R. 409 and Isopestox give a very high mortality 64 hours after spraying.* This effect disappears fairly quickly and, after a time interval, while newly exposed aphids are still being killed, the newly exposed beneficials survive.

In a wide range of experiments carried out in England, and in Africa, the same effect on larvae of Syrpha sp., the Braconid *Aphidius brassicae*, the red spider *Tetranychus telarius*, and its predator, the Anthocorid *Blepharidopterus angulatus* was observed (Table 3).

While *Schradan*, in these experiments, proved to be a selective insecticide, *C.R.*

[1] Known as *OMPA*, *Pestox 3* and *Schradan*.

Table 1.—Mortality of the cabbage aphis and its enemies exposed on plants sprayed with systemic insecticides at rate of 2 cc. per plant.

Insect	Insecticide	Concentration Per Cent	Percentage Mortality After 24 Hours	10 Days	20 Days	30 Days	40 Days
Brevicoryne brassicae	*Schradan*	0.4	95	86	83	22	8
Brevicoryne brassicae	*C.R. 409*	0.4	100	88	62	21	9
Brevicoryne brassicae	*Isopestox 15*[2]	0.4	100	57	19	9	5
Brevicoryne brassicae	*Pestox 16*	0.4	97	24	11	7	5
Brevicoryne brassicae	Control	—	3	2	3	3	2
Coccinella septempunctata	*Schradan*	0.4	0	2	0	0	0
Coccinella septempunctata	*C.R. 409*	0.4	100	12	2	0	0
Coccinella septempunctata	*Isopestox 15*	0.4	100	4	0	0	0
Coccinella septempunctata	Control	—	0	0	1	0	0
Syrphid larvae	*Schradan*	0.4	0	0	0	0	0
Syrphid larvae	*C.R. 409*	0.4	100	6	0	0	0
Syrphid larvae	*Isopestox 15*	0.4	100	0	0	0	0
Syrphid larvae	Control	—	0	0	0	0	0
Aphidius brassicae	*Schradan*	0.4	25	0	0	0	0
Aphidius brassicae	*Schradan*	0.2	8	0	0	0	0
Aphidius brassicae	*C.R. 409*	0.4	100	4	0	0	0
Aphidius brassicae	*Isopestox 15*	0.4	100	0	0	0	0

[2] A systemic insecticide containing bis-monoisopropylaminol fluorophosphine oxide.

409 and *Isopestox* did not. The fact that the latter systemics lose their toxicity to predators so much earlier than their toxicity to plant sucking pests is explained by the absorption of the systemic insecticide into the leaf.

Heath & Llewellyn have shown by the radio tracer technique, that systemics are taken up into the leaf from a spray deposit at a rate very much dependent on species and state of growth. An average figure for most outdoor crop plants in summer when using the standard formulation of *Schradan* with wetting agent is about 5 to 6 per cent of the applied spray per hour. Greenhouse seedlings absorb very much faster. Dry hot weather is favourable to absorption, provided the leaf is not badly wilted, but fatally wilted leaves absorb extremely slowly. Some old leaves become non-absorptive late in the season. This is particularly true of hops.

Penetration into the plant tissues from the leaf surface involves the passage of more than one barrier. After a few hours in dry weather there is no detectable liquid residue, the insecticide having penetrated into the capillary spaces, but a considerable amount may be easily washed out. In most cases after 24 hours, very little can even be washed out. Beneficial insects are therefore not killed after all the spray residue of the systemic has been absorbed.

This gave us the idea of the means to *convert the non-selective systemics* which are well translocated, *into insecticides with selectivity*. We tried to apply them in such a way that they do not come into contact with those plant organs where the beneficials occur; for instance we tried to apply them to the root system or to the seed, in cases where the object is to control plant sucking insects feeding on the leaves without harming their predators or parasites.

This can be effected by spraying or pouring the systemic preparations on the soil near the plant to be protected or, in irrigated crops, by introducing the systemic into the irrigation water.

In the following table, experiments are

Table 2.—Mortality of cabbage aphis and percentage of emergence of *Aphidius brassicae* from cabbage aphis mummies after *Schradan* treatment by spray application.

Schradan Concentration	Dosage per Acre	Date of Spraying	Date of Counting	Mortality of Aphids	Parasitized Aphids	Per Cent *Aphidius* Reared
0.4%	100 gal.	Sept. 23	Sept. 30	100	47	59
0.2	100 gal.	Sept. 23	Sept. 30	90	55	65
Control	—	—	Sept. 30	8	50	70

Table 3.—**Mortality of the red spider, *Tetranychus telarius*, and one of its predators, *Plepharidopterus angulatus*, exposed on hop plants sprayed with systemic insecticide at the rate of 10 cc. per plant.**

Insect	Insecticide	Concentration (Per Cent)	Percentage Mortality of Red Spider After 24 Hours	10 Days	20 Days	30 Days
Tetranychus telarius[1]	*Schradan*	.4	100	85	60	30
Tetranychus telarius	*C.R. 409*	.4	93	70	14	14
Tetranychus telarius	*Isopestox*	.4	100	100	83	83
Tetranychus telarius	*Pestox 16*	.4	100	58	6	5
Tetranychus telarius	Control	—	5	5	5	5
Plepharidopterus angulatus[2]	*Schradan*	.4	0	0	0	0
Plepharidopterus angulatus	*C.R. 409*	.4	98	12	0	0
Plepharidopterus angulatus	*Isopestox*	.4	92	7	1	0
Plepharidopterus angulatus	Control	—	0	0	1	0

[1] Number of red spider per exposure: 20 females, 4 repetitions for each mortality.
[2] Number of *Plepharidopterus* per experiment: 15 females, 3 repetitions for each mortality.

recorded where the systemics were applied to the soil or the irrigation water, and it is observed that *C.R. 409* and *Isopestox* affect the beneficial insect in the same way as *Schradan*, namely not at all (Tables 4 and 5).

In Table 6 the effect of *C.R. 409* on *Pseudococcus* feeding on tall trees of 10 to 13 inches girth when applied by spray or soil treatments is compared. The comparison shows that a better control is obtained by application to the soil than by spraying. The predators found on the mealybug colonies were *coccinellids*, *syrphids*, *Coleopterous* larvae and *arachnids*, none of which was affected by the soil treatment.

In large scale experiments with cabbage aphis in Bedfordshire, repeated over 2 years, Goscombe showed (Fig. 1) that, as a result of the application of *Paraoxon* or parathion, a rapid re-infestation occurred, necessitating a repetition of the spraying, whereas during the bad cabbage aphis outbreak of 1949 in England, one application of *Schradan* kept the crop free of cabbage aphids all summer. The yield

Table 4.—**Mortality of the cabbage aphis *Brevicoryne brassicae*, its parasite, *Aphidius brassicae*, and its predators *Coccinella septempunctata* and Syrpha sp. exposed on plants after soil treatment with systemic insecticides**

Insects	Insecticide	Concentration (Per Cent)	Dosage per Plant (cc.)	Percentage Mortality After 24 Hours	10 Days	20 Days	30 Days	40 Days
Brevicoryne brassicae	*Schradan*	.4	2	52	69	18	0	0
Brevicoryne brassicae	*Schradan*	.4	5	82	53	45	30	16
Brevicoryne brassicae	*Schradan*	.4	10	96	82	78	60	14
Brevicoryne brassicae	*C.R. 409*	.4	2	65	89	27	0	7
Brevicoryne brassicae	*C.R. 409*	.4	5	78	86	54	15	4
Brevicoryne brassicae	*C.R. 409*	.4	10	92	100	73	15	3
Brevicoryne brassicae	*Isopestox*	.4	2	60	71	32	11	0
Brevicoryne brassicae	*Isopestox*	.4	5	83	79	41	17	5
Brevicoryne brassicae	*Isopestox*	.4	10	93	94	52	11	8
Brevicoryne brassicae	Control	—	—	0	4	0	8	3
Aphidius brassicae	*Schradan*	.4	10	0	0	2	0	0
Aphidius brassicae	*C.R. 409*	.4	10	8	4	0	0	0
Aphidius brassicae	*Isopestox*	.4	10	0	0	1	0	0
Aphidius brassicae	Control	—	—	2	0	0	0	1
Coccinella septempunctata	*Schradan*	.4	10	0	0	0	0	0
Coccinella septempunctata	*C.R. 409*	.4	10	7	0	0	1	0
Coccinella septempunctata	*Isopestox*	.4	10	0	0	1	0	0
Coccinella septempunctata	Control	—	—	0	0	0	1	0
Syrphid larvae	*Schradan*	.4	10	0	0	0	0	0
Syrphid larvae	*C.R. 409*	.4	10	0	1	0	0	0
Syrphid larvae	*Isopestox*	.4	10	0	1	0	5	0
Syrphid larvae	Control	—	—	0	0	0	0	0

Table 5.—Mortality of the red spider *Tetranychus telarius* and one of its predators *Plepharidopterus angulatus* exposed on plants after soil treatment with systemic insecticides.

Insect	Insecticide	Concentration (Per Cent)	Dosage per Plant (cc.)	Percentage Mortality Red Spider After 24 Hours	10 Days	20 Days	30 Days
Tetranychus telarius[1]	*Schradan*	.4	10	93	96	60	28
Tetranychus telarius	*C.R. 409*	.4	10	90	93	80	13
Tetranychus telarius	*Isopestox*	.4	10	100	100	90	17
Tetranychus telarius	Control	—	—	3	0	2	0
Plepharidopterus angulatus[2]	*Schradan*	.4	10	0	0	0	0
Plepharidopterus angulatus	*C.R. 409*	.4	10	5	0	0	0
Plepharidopterus angulatus	*Isopestox*	.4	10	0	0	1	0
Plepharidopterus angulatus	Control	—	—	0	1	0	0

[1] Number of red Spider per exposure: 20 females, 4 repetitions for each figure.
[2] Number of *Plepharidopterus* per experiment: 15 females 3 repetitions for each experiment.

increase in Brussels sprouts of marketable quality from the *Schradan* sprayed plots was 82 per cent above the untreated control, while the Parathion sprayed field showed an increase of 22 per cent.

In strawberry fields a very rapid increase in the aphid population after parathion spraying within 14 days was obtained, while on the *Schradan* sprayed plots the aphid population remained very low (Fig. 2).

We therefore seem justified in concluding that:

(a) Systemic insecticides such as *Schradan* makes plants toxic to sucking pests without making them toxic to beneficial insects when sprayed on to the leaves of the plant or applied to the root system either by direct treatment of the soil or by addition to the irrigation water. By any of these means the plant is rendered toxic to aphids and red spiders for a prolonged period varying from three to six weeks during the growing season, and for much longer periods when the plant is less active.

(b) The above treatment prevents the quick build up of pest populations which occur after the application of conventional insecticides such as parathion, DDT, BHC etc.

(c) Non-selective systemic insecticides can be used to produce a selective effect if they are applied to the soil near the root of the plant to be protected, either directly or by the admixture with the irrigation water. In this case, translocation is effected into the leaves to an extent sufficient to kill aphids, mealybugs, white flies, thrips, jassids and red spider without causing interference with beneficial insects.

Selective insecticides may therefore be classified according to the nature of the selectivity, as follows:

(a) insecticides which, owing to physiological difference between pests, predators, and parasites, kill the pests at a concentration which does not affect the beneficial insects; we propose to refer to this as "*physiological selectivity.*"

(b) selective insecticides in which the differences in the ecology of the pests and the beneficial insects is used as a basis of the selective effect. We propose to refer to this as "*ecological selectivity.*"

Ecological selectivity is produced in systemics by exploiting the possibilities offered by the translocation which the plant effects with systemics, and this phe-

Table 6.—Mortality of the mealybug *Pseudococcus kenyae* on coffee trees after treatment with the systemic insecticide *C.R. 409*.

Concentration (Per Cent)	Number of Mealybugs	Mortality After 1 Week	2 Weeks
Spray Treatment			
1	443	54.8	52.8
.7	434	50.1	33.1
.5	325	30.4	24.6
.3	424	21.2	28.9
—	585	12	12

Amount Active Ingredient (Gms.)	Dosage per Tree (cc.)	Number of Mealybugs	Girth of Tree (Inches)	Mortality After 2 Weeks	4 Weeks	8 Weeks
Soil Treatment						
16	160	511	13	89	99.7	99.6
10	80	359	10	87	99.4	97.6
8	40	551	12	53	90.2	94.2
4	20	471	13	48	72	59
2	10	536	17	40	39	49
—	—	431	12	1	15	12

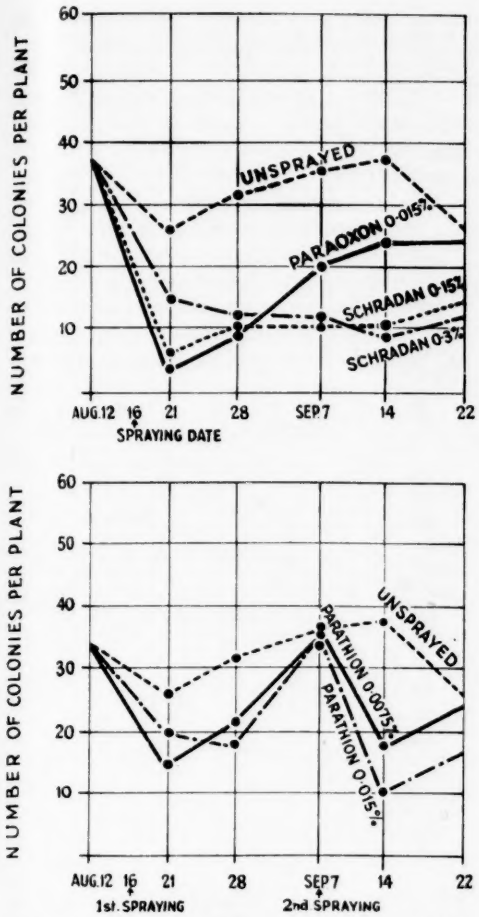


FIG. 1.—Population density of the cabbage aphis (*Brevicoryne brassicae*) after spray treatment with Parathion 0.015% and 0.0075%, Paraoxon 0.015%, and *Schradan* 0.15% and 0.3%.

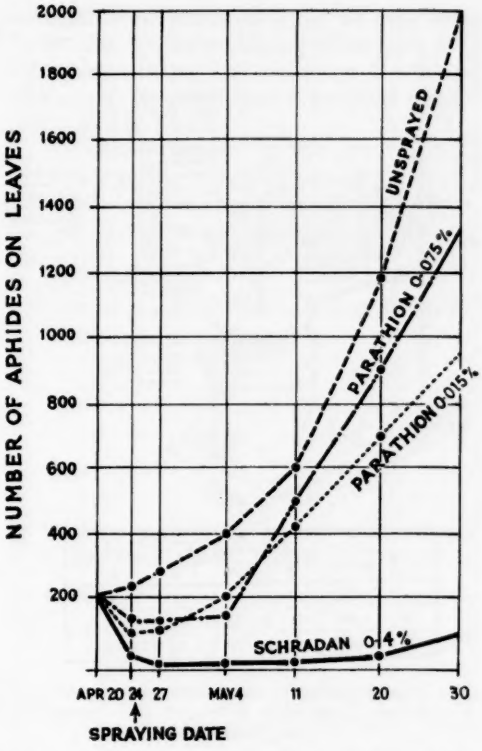


FIG. 2.—Population density of the strawberry aphis (*Capitophorus fragariae*) after one spray treatment with parathion 0.015% and 0.0075% and *Schradan* 0.04%.

nomenon may therefore warrant a short discussion, based on our work with *Schradan*, the best explored systemic.

TRANSLOCATION OF SYSTEMIC INSECTICIDE.—The methods used involve the application of the insecticide to a confined space on to parts of the plant (Fig. 3) and a study of its translocation to other parts by:

(a) observing the mortality of the pests (20)
(b) chemical analysis
(c) the use of radio tracer method.

The last method involves the labelling of systemic compounds by the radioactive P^{32} into its molecule.

Results obtained by any of these methods, details of which are being described elsewhere, are in close agreement, and show that:

(a) treatment of the soil will give translocation upwards.

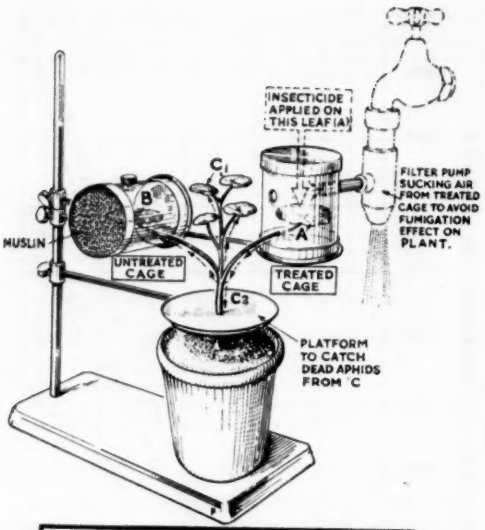
(b) spray treatment of the stem or leaves will give translocation below and above the treated spots (Figs. 4 and 5).

(c) the uptake is best in leaves which are just fully opened, is not so good in younger leaves, and is still less in leathery old leaves.

(d) in beans and peas, the systemic insecticide is translocated from leaves to pods.

(e) parts of the plant which were not present at the time of spraying, including seeds not then formed, will become toxic through translocation from the sprayed older parts.

(f) if a seed is soaked or coated with a systemic insecticide, the insecticide is translocated into the young plant which may be many times the weight of the seed



LEAF	NO. OF APHIDS	PERCENTAGE MORTALITY AT DIFFERENT TIMES AFTER TREATMENT (HOURS)			
		3	20	27	41
A	86	10·4%	95·3%	100%	100%
B	46	2·1%	76·0%	84·7%	100%
C	153	1·9%	79·8%	95·4%	100%

FIG. 3.—Apparatus to demonstrate translocation of a systemic insecticide *Schradan* in Tropaeolum using *Aphis fabae*.

(Ripper 1950; Ivy *et al.* 1950; Chao Sang Tsi 1950)

TENACITY OF TOXIC ACTION AND DECOMPOSITION OF THE SYSTEMIC INSECTICIDES.—The duration of the insecticidal

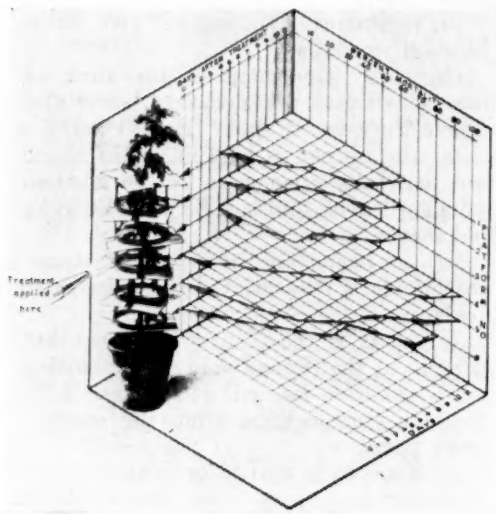


FIG. 4.—Mortality of the chrysanthemum aphis (*Coloradoa rufomaculata*) after treatment of a section of the chrysanthemum plant with *Schradan*.

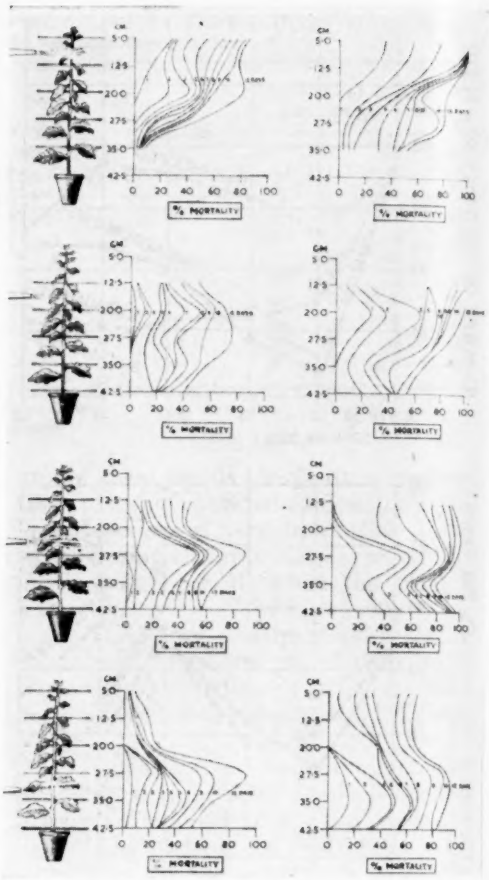


FIG. 5.—Mortality of *Macrosiphoniella sanborni* and *Coloradoa rufomaculata* after treatment of a section of the chrysanthemum plant. The curves represent the mortality after 1, 2, 3, 5, 6, 7, 8, 9 and 12 days.

effect is limited by the decay of *Schradan* when exposed to the enzymes of the plant The decay is not due to inanimate hydrolysis. This latter phenomenon has been thoroughly investigated in our laboratories by Heath and the results will shortly be published. Figure 6 shows the behaviour of the more simple and related hexamethyl-ortho-phosphoramide, which is not insecticidal. Both this compound and *Schradan* are very stable in water. In the normal range of plant pH of 4–6, the inanimate half lives would run into years. Strongly acid solutions hydrolyse the P-N link. Strongly alkaline solutions hydrolyse the P—O—P link and therefore do not affect the orthoamide. Powerful oxidising agents and chlorine attack the compound at the nitrogen atom.

In the plant, Heath & Llewellyn find

that radioactive *Schradan* supplied to the plant is decomposed much more rapidly than inanimate hydrolysis could explain. To demonstrate this, the plant tissues are macerated with water, filtered, and the filtrate treated with caustic soda and extracted with chloroform. The radioactivity of each layer is measured in a Geiger-Müller counter. It can be shown that the chloroform layer contains nothing but unchanged *Schradan* and further extraction of the aqueous layer with chloroform yields nothing but a small amount more *Schradan*, the remaining activity being due to

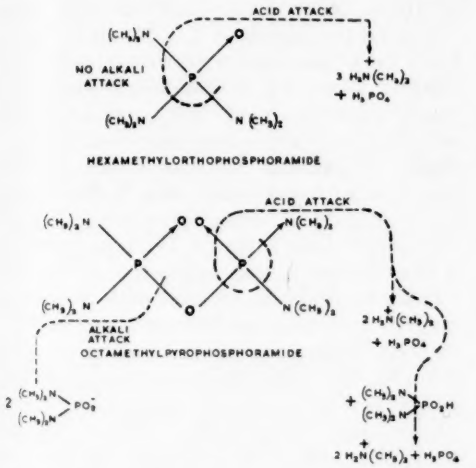


FIG. 6.—Inanimate hydrolysis of hexamethyl ortho phosphoramide and *Schradan* (octamethyl pyro phosphoramide).

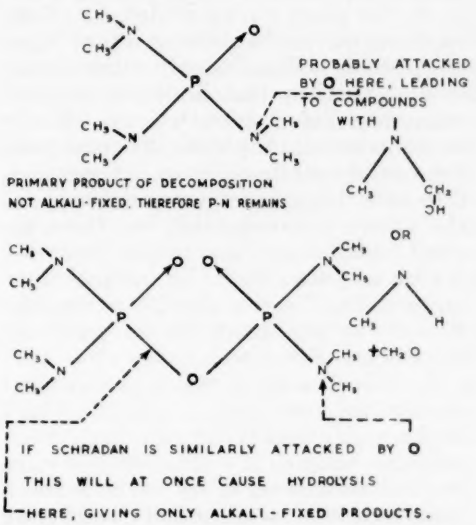

PROBABLY ATTACKED BY O HERE, LEADING TO COMPOUNDS WITH
PRIMARY PRODUCT OF DECOMPOSITION NOT ALKALI-FIXED, THEREFORE P-N REMAINS
OR
IF SCHRADAN IS SIMILARLY ATTACKED BY O
THIS WILL AT ONCE CAUSE HYDROLYSIS
HERE, GIVING ONLY ALKALI-FIXED PRODUCTS.

FIG. 7.—Probable decomposition in the living plant of hexamethyl ortho phosphoramide and *Schradan* (octamethyl pyrophosphoramide)

decomposition products not extractable by chloroform from alkali.

The hexamethyl-ortho-amide is decomposed by the plant at about the same speed as *Schradan* but, in this case there appears a new compound still extractable by chloroform from alkali but to a much smaller extent. This leads us to a very probable guess as to the mode of decomposition (Fig. 7).

If the P—N link is broken, an acidic group must be left on the phosphorus and the product will not be extractable from alkali. Therefore the attack must be in the outer part of the molecule. Oxidising agents are known to remove methyl groups by a series of complex reactions and it is most probable that the enzymic reaction is an oxidising one leading to removal or substitution of a methyl group. That no new extractable compounds is derived from *Schradan* itself we conclude to be due to the oxidising attack on the nitrogen causing fission of the P—O—P link which is not of course possible in the ortho-amide.

The decomposition in the plant is not only very much faster than *in vitro* hydrolysis but it proceeds by a radically different mechanism—yet another example of the great gulf between living and laboratory chemistry.

Typical results of the decomposition of *Schradan* in the *plant* obtained by the radioactive technique were obtained by the analysis of random samples from whole strawberry plants at intervals after a single spraying. Not only was the *Schradan* decomposed but there was also a loss of tracer phosphorus, probably by excretion by the root. The spraying dosage was three times as high as is normally recommended. Similar analytical data show the sequence of decomposition in sprouts sprayed in August (Fig. 8), and mid-October (Fig. 9). The decomposition is much slower in late autumn than when the plant is in vigorous growth.

The period over which the plant retains its toxicity depends upon the decomposition of the systemic and this in turn depends upon the time of the year and the physiological activity of the plant. During the summer, when the plant is growing

actively, toxicity disappears much more quickly—the half life for *Schradan* being 2 to 3 weeks (Table 7), that of the new ecologically selective systemic *Pestox 15*, 6 days (Fig. 10), and that of *C. R. 409*, 1 to 2 weeks (Fig. 11). After an application in late autumn, toxicity in strawberry plants was observed four months later. As the days shorten, and the assimilation and therefore translocation of metabolic substances in the plant subsides, so also will the absorption and decomposition of systemic compounds. To effect lasting toxicity in the plant during winter, therefore, application must be made at a time when the plant is still sufficiently active to ensure absorption, that is during late autumn just before growth ceases. Under such conditions, the plant will remain toxic for several months. During dry weather, if there is no water deficiency in the plant, the uptake is accelerated, but there are other conditions under which absorption is slow or non-existent, for instance, during periods of severe drought, when the flow of the sap stream in the water deficient plant is reduced.

As *Schradan* decomposed in the plant during the growing season within 3 to 4 weeks, after 6 weeks after spraying no toxic residue remained. It is therefore necessary to have an interval of six weeks between spraying and harvesting, and the spraying program must be planned accordingly.

Data on spray residues on 150 acres of strawberries which were treated with 1.5 lbs. of *Schradan* in 100 gallons of water per acre show an interval of 6 to 8 weeks between spraying and analysis (Table 8). Out of these 24 separate analyses only five exceeded the blank of 1.0. Similar results have been obtained with other plants including hops. All *Schradan*-sprayed hopyards were sampled last year and the samples analysed before harvesting, six to eight weeks after the last spraying. No spray residue exceeding the blank figure was obtained. In these cases the *Schradan* was applied as a spray. We now turn to a case where it was applied via the soil (Table 9). Soil was treated with *Schradan* to give an estimated 250 parts per million in the soilwater which was protected from leaching. Dahlia tubers were inserted in the top layer of soil. Successive shoots above 4 inches high were removed entirely and analysed, others being allowed to grow. It will be seen that although the decomposition in the green shoot is comparable with what we have found before, the new shoots are still receiving little less *Schradan* from the soil after 70 days. This

Table 7.—Time interval in which *Schradan* is reduced to half the original concentrations by hydrolysis at 25° C. (Half Life).

pH	Hydrolysis	
	Inanimate	Animate
1	35 hours	
3	146 days	2 to 3 weeks
5	40 years	2 to 3 weeks
7	10 years	2 to 3 weeks
9	100 years	
11	100 years	
13	20 months	

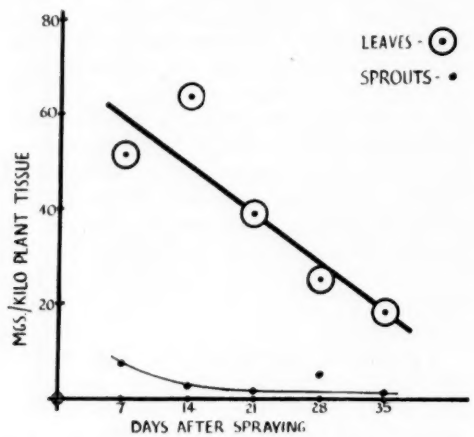


FIG. 8.—Spray residues of *Schradan* in Brussels sprouts sprayed in August.

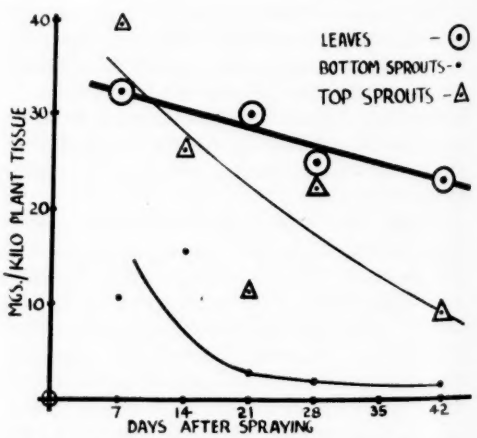


FIG. 9.—Spray residues of *Schradan* in Brussels sprouts sprayed in October.

Table 8.—Spray residues on strawberries sprayed in 1950 with 1.5 lb. *Schradan* (*Pestex 3H*, 67 per cent or equivalent of 30 per cent) in 100 gal. of water per acre.

SAMPLE NO.	DATE SPRAYED	DATE SAMPLED	*Schradan* IN P.P.M.
K.1	5- 4-50	6-13-50	0.7
K.2	5- 4-50	6-13-50	2.0
K.3	4-30-40	6-15-50	0.4
K.4	4-30-50	6-15-50	0.3
1 H.1	4-20-50	6-14-50	0.7
1 H.2	4-21-50	5-14-50	0.5
1 H.3	4-21-50	6-14-50	1.6
1 H.4	5-21-50	6-14-50	1.5
1 H.5	4-26-50	6-14-50	0.3
1 H.6	4-21-50	6-13-50	1.0
1 H.7	4-26-50	6-14-50	0.3
1 H.8	4-28-50	6-14-50	0.2
1 H.9	5- 1-50	6-13-50	0.5
1 H.10	5-28-50	6-14-50	0.3
1 H.11	4-20-50	6-14-50	0.4
1 H.12	4-20-50	6-14-50	0.3
1 H.13	4-20-50	6-14-50	0.2
1 H.14	5-20-50	6-14-50	0.1
1 H.15	4-30-50	6-14-50	0.2
E.2	4- 6-50	6-22-50	0.7
DM.1	5-11-50	6-16-50	0.5
S.1	5- 1-50	6-22-50	0.4
W.1	5-10-50	6-26-50	1.5
B.1	Unsprayed	6-25-50	1.0

suggests that decomposition in soil is very much slower than in growing green plants.

METHODS OF APPLICATION.—In all laboratory and greenhouse experiments with systemic insecticides it is important to make sure that the room where the plants are kept is well ventilated and, if individual containers of insects are fixed to the plant, these are well aerated.

Table 9.—Residues of *Schradan* in shoots of Dahlia planted in soil to which Schradan was applied so that the soilwater contained 250 mg./kg.

DAYS AFTER SOIL APPLICATION	APPROXIMATE AGE OF SHOOTS (DAYS)	MG. *Schradan* PER KG. TISSUE	DECOMPOSITION PRODUCTS MG./KG.
18	14	63	28
32	20	23	19
38	14	58	33
70	30	49	29

When a systemic insecticide is applied in the field we have to distinguish between application to the soil and spraying. The former can be carried out by spraying machines specially adapted to apply the chemical close to the base of the plant, by soil injectors, or by the addition of the systemic to the irrigation water, using methods similar to those developed for the introduction of liquid ammonia into the irrigation water.

Where spraying methods are employed the toxic nature of the most systemic insecticides requires attention. Although our research effort is concentrated on compounds which are not of the highest toxicity a great deal of care is necessary. Alarmed by previous experiences with parathion, we have gone to great trouble to safeguard the health of our agricultural workers, operating on the principle that the worker must be protected from any contamination. We provide this protection

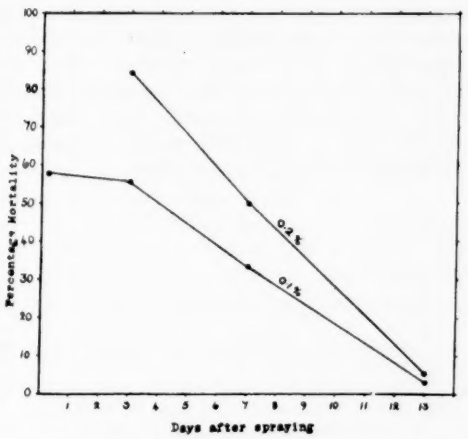


FIG. 10.—Persistence of mortality of the Chrysanthemum aphis, *Coloradoa rufomaculata*, when fed for 24 hours on plants sprayed with *Isopestox*.

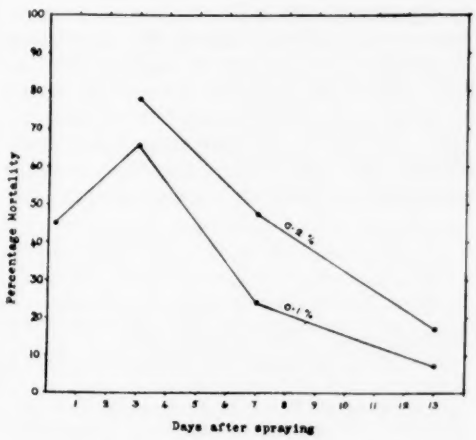


FIG. 11.—Persistence of mortality of the Chrysanthemum aphis, *Coloradoa rufomaculata*, when fed for 24 hours on plants sprayed with *C.R. 409*.

in the form of the so-called gas-proof air-conditioned cabs. In addition we take a number of precautions which have been worked out during the last 4 years and which we introduced 2 years ago as our "Eight Point Safety Code." Since the introduction of this code into our Contract Spraying Organisation, we have not had a single accident. This safety code has now found a measure of official recognition and the Association of British Agricultural Contractors has undertaken that all its members will adopt it. While mentioning this, I do not wish to create the impression that these systemic insecticides are more toxic than many other insecticides in general manufacture and use.

For spraying systemic insecticides the conventional method of high volume spraying is useful but important saving in water transport can be achieved by the use of a low volume sprayer, and we have established that the low volume tractor-mounted or tractor-driven spraying machine, or the aerial spraying machine, is adequate and that far less uniform cover is necessary with systemics than with the conventional insecticides. Moreover, as H. Martin (1950) pointed out, the greater health hazard attendant upon the use of these low volume applicators when non-systemics are used, is avoided.

Low volume sprayers—in particular, atomisers,—have the disadvantage that surplus spray deposits do not run off as is the case when high volume sprayers are used, but stick to the old plant and lead, in the case of conventional insecticides, to an excessive concentration and sometimes to phytocidal damage or high toxic residues. When a systemic is used the plant absorbs and redistributes the surplus deposit. Thus, on beet and hop it has been shown that an application of a certain quantity of *Schradan*, in 100 gallons per acre, was no more effective than the same quantity in 4 gallons per acre. This is obviously a great advantage in air spraying because it makes the initial uniformity of spray cover much less important.

Field experience in England has shown that the introduction of systemics leads to a reduction in the number of spray applications per year; consequently the farmer finds the treatment of crops simpler and cheaper. It may also lead to a reduction in the quantities of spray chemicals used, and some modification in our application technique, and will demand considerable re-orientation of our spray chemical manufacture.

CONCLUSION.—The combination of selective and systemic toxicity offers great possibilities for the utilisation in agriculture of the vast knowledge already accumulated on biological control of pests.

A great deal remains to be done for we have not yet proved the second working hypothesis mentioned above although its validity seems probable—namely, that after treatment with a selective insecticide, resistant mutants of the pest population, which survive spray treatment, will be destroyed by the beneficial insects and, thus, the segregation of strains of pests resistant to the insecticides will not occur.

This and a large number of other epidemiological questions connected with the relative importance of biological control can be elucidated by the use of systemics.

It is appreciated that the selective insecticides discussed here deal only with a section of today's pest problems, but the principle is obviously capable of wider application. It is our conviction that the advent of chemotherapy in entomology will bring biological control to the fore and in agriculture will mean as great a progress as it has in medicine.

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Insects, Man and the Environment

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Economic entomology is concerned with problems connected with insect populations which threaten the crops and produce of mankind. It deals with the control or limitation of those populations within the habitat in which they occur and is therefore primarily occupied with problems which have an essentially ecological background. To be rational, therefore, the methods employed in the course of its investigations should be based upon a thorough cognizance of the ecology of the insects concerned.

It follows that the economic entomologist should be thoroughly conversant with the principles, methods and aims of ecology. Unfortunately, he is often lacking in the essential groundwork of this subject; or, if he has received adequate training, his professional career encourages him to ignore it in his daily work. He ceases to be a biologist and, in the majority of cases, becomes, in effect, a mere tester of poisons or an insecticide salesman.

The ecologist regards the environment and the organisms which inhabit it as an organic whole. It must be studied as such in order to be able to understand the natural limitation of populations therein and to develop additional methods of meeting the practical problems of control to which it gives rise. Studies of single organisms, in which they are treated as isolated individuals or problems, do not serve the purpose adequately, even though they are so studied in their native habitat. Before we can obtain a normal picture of field events we require to know something of the interrelationships between organism and environment and between the different species which frequent the latter. Without this knowledge we blunder among the intricate patterns of life in the biota and, in doing so, we create chaos and additional problems where once there was a semblance of order.

Furthermore, man himself must be re-

Biological Control, SYMPOSIUM PAPER, Denver Meeting, 1950

garded as merely an important biotic part of the environment. He lives or works within it and, while so doing, profoundly influences not only his immediate surroundings but also the cohabitant fauna. Because of this and of his more highly developed way of life, man has an immeasurably greater over-all effect than have the lower animals. His activities bring about gross alterations in the environment extending over relatively large areas.

These often have extremely drastic effects upon the smaller fauna, the composition of which, over a given area, may undergo a radical change as a direct consequence. One has only to consider the effects produced by the wholesale clearance of the natural forests, not only upon the fauna and flora but upon the physical features of a region as well; or the development of agriculture with its concentration of one species of host-plant over an area and hence the inauguration of a highly specialized type of environment which is essentially artificial and which serves to attract a limited number of different species of organisms.

It is necessary, here, to emphasize the importance of this and other results of man's activities in the production of his elemental needs on the rise of insect populations until some, at least, have become numerous enough to constitute major competitors of man for the results of his labours. A condition which existed prior to the advent of civilization but which, at that time, was barely noticeable, has now assumed serious proportions and demands attention lest it should deprive man of too great a share of his food supply. The important point here is that this situation has arisen mainly as a direct consequence of extensive *interference* with the natural environment.

In areas in which the practice of agriculture is still in a primitive stage of development and where the method of growing crops most nearly approaches conditions found in Nature as, for example, in parts of Asia, we do not often encounter any serious problems arising from insect pests. Here, there is the minimum of interference with Nature and events proceed much as they do in the undisturbed habitats. A state of "balance" is maintained in which no one species assumes undue proportions. In more advanced areas, however, the interference is greater and the situation deteriorates in proportion to this, so that the number of species in an area becomes progressively fewer while the number of individuals of each species remaining tends to increase until outbreaks may eventually constitute a normal feature of the environment.

It is here that the situation becomes sufficiently serious to demand some action from man to counteract the ill effects upon his food supply. The problem was originally tackled much as was that of competition for living space, for hunting grounds and the like, between the tribes or races of primitive man, *i.e.*, by the attempted elimination of the competing population. This has gone on through the ages, gradually becoming intensified as the problems became more acute and as the development of techniques advanced with the discovery of insecticides and the production of increasingly more powerful poisons which could be used for destroying insect populations. It is clear that the advances have been mainly along purely technological lines and that the underlying principles involved in this kind of control are still identical with the crude formulations of the primitive brain. We continue in the same path in the vain hope that we shall eventually evolve some all-powerful remedy which will solve our insect problems once and for all.

Experience with insecticides to date should have taught us that this hope is unlikely to be realized. Our most potent poisons today are clearly creating problems themselves—problems which did not exist before their advent and use in the field. To introduce such materials into an environment is to add to the chaos which originated with the artificiality of the crop environment. To provide a factor producing catastrophic mortality on an extensive scale and of a type foreign to nature, is to enact an even more profound interference with faunal relationships than hitherto.

Two of the many possible results of such a procedure may be mentioned here since they have an important bearing upon the later course of events in an environment so misused. One is the differential effect which many of these chemicals have on the various species in the environment; the second effect is that

of the gradual or rapid development of resistance to such chemicals by the insects which they are specifically intended to destroy. Examples are sufficiently well known to make it unnecessary for me to elaborate on them here.

Both of these effects may be responsible for the appearance of new pests or an intensification of the problems presented by the old. I want to emphasize that, in this instance, we are faced with an upheaval in the interrelationships between the species present consequent upon interference with the environment of a profound and far-reaching character. The destruction of natural enemies of insects, together with the inherent plasticity of organisms to adapt themselves to adverse conditions in the environment are among the main factors concerned in the phenomena produced. Ignoring this, or failing to recognize it, has been one of the main causes leading to the major problems of today.

Can we retrace our steps and retrieve the situation in any appreciable measure? I think we can if we do not delay the effort too long. A number of workers have come to recognize this necessity and to publicly pronounce it (see, for example, Ullyett 1947;[1] Pickett 1949[2]) but that number still forms all too small a proportion of the entomological profession as a whole.

In our dealings with pest problems, we inadvertently or of set purpose overlook the salient fact that we frequently find a reasonably successful method of regulating the abundance of species in the natural, undisturbed environment—a method which, complicated and somewhat variable in character though it may be, and fallible though it may prove on occasion, is sufficiently well established to be recognized. It is a method which evolves from the complex interactions of the biotic and abiotic components of the environment and in which there is a tendency towards a state of "balance" in which no one organism shall multiply unchecked to the detriment of its fellows or of the environment itself. In those areas where the natural environment has been partially or wholly replaced by the more artificial conditions consequent upon agricultural development, the whole make-up of the area becomes changed and unlike anything to be found under primitive conditions. Many of the features no longer approach natural ones, e.g., the planting of large areas to pure stands of trees or crops; the cultivation of the soil and the consequent absence of undergrowth; the use of irrigation and so forth.

Because of this appearance of new and foreign conditions, natural methods may no longer cope with the situation as completely and efficiently as before. In particular, the normal diversity of plant species in Nature is replaced by uniformity which, in turn, is accompanied by a tendency for uniformity in the insect fauna. The difficulty created is most apparent during the early stages of the new habitat, *i.e.*, before any adaptations can occur. It seems likely that, over the years, some adjustments to the altered conditions may gradually become evolved. Just as the organism itself is endowed with the power of adaptation, so the environmental complex is also characterized by a degree of plasticity which eventually tends towards a new stable condition which is peculiarly adapted to the physical environment.

In some cases, such adjustments are already evident. In the meantime, problems may arise because of the inability of the factors of natural control to take care of the situation in its entirety. In some cases, of course, the essential factors of natural control may be absent, perhaps due to unsuitable environmental conditions, pre-existing or otherwise, and in such cases we can obviously not look to natural control to perform any useful function. But I am concerned, here, with the far more common occasions on which the factors are present or can become established and with those areas in which they are able to work. At some point in the chain of events, weaknesses in these factors afford the opportunity for population expansion by some one species which may then prove to be a serious pest of economic crops.

In spite of this, however, *some* degree of control is usually still maintained over species in these new habitats, even though this is not sufficient to keep the species in check. Some, if not all, of the essential elements are generally available in some measure. Only the gross interrelationships between flora, fauna and physical factors, and only the overall specific composition of the biota are now changed. The old

[1] Ullyett, G. C. 1947. U. S. Africa, Dept. Agr. Ent. Memoirs 2(6): 77–202.
[2] Pickett, A. D. 1949. Can. Ent. 81: 67–76.

regime no longer exists. If we recognize this and remember, at the same time, that natural control factors may still play a not inconsiderable part, then we can surely devise some intelligent method of pest control in which we make use of these factors as far as they can help us while supplementing them by handling the aspects which are beyond their scope and which are due solely to our own agricultural practices. Under our present-day popular ways of treating insect problems the possibility of using the help of the factors of natural control is almost entirely ignored.

At the root of the matter is the fundamental greed of mankind. We are not content to share *any* of our produce with the insects; we are not prepared to make any allowance for them within our environment. Our ideal, which is always held in the foreground, is "100 per cent destruction" of these competitors—an ideal which has so far proved impossible of attainment in large-scale practice and which is unlikely ever to be realized.

Our attitude is directly opposed to the events in nature. Here, no elimination of any one species is so readily achieved, nor does the mechanism of mortality normally assume a form whereby such a result could be obtained. Only under exceptional environmental conditions does this occur, e.g., in "closed" environments. We find that provision may be made not only for an adequate *destruction* of individuals of a population so that the latter does not assume an unduly high density, but there is a strong tendency also for the *maintenance* of each species within the environment so long as the latter remains physically suited to it. What is indicated, therefore, is the establishment and maintenance of something approaching a state of "balance" between the species in the habitat so that all tend to survive but do so in numbers which do not constitute what we describe as "outbreak" proportions. This balance will inevitably be an unstable state but may be such that the fluctuations which take place in it are never such that the abundance peaks of the insect populations overstep the economic level.

When we try to eliminate certain species from the environment by the use of more and more powerful poisons, we are going further and further from the elemental principles of natural control. In doing so, we more often than not destroy more individuals of the natural enemies of a pest than we do of the pest itself. As a consequence, together with the inherent aptitude of organisms to develop resistance to a catastrophic mortality factor which is frequently applied (*e.g.*, in the case of codling moth and scale insects), we have to face ever-increasing difficulties in our control problems. The worst infestation of codling I have ever seen followed an insecticidal programme consisiting of no less than 17 applications of lead arsenate during a single season.

To meet these difficulties, we blunder blindly along the same narrow path as our ancestors, looking neither to right nor to left, until we shall eventually reach the end beyond which no further progress is possible in this direction. By that time, we shall be facing a situation in which our insect competitors have the upper hand. Furthermore, since we are "economic" entomologists, we may, if we take careful stock during the later periods, find that we have been spending more on control measures than is warranted by the true value of the food stuffs which we have attempted to protect thereby.

How, then, can we remedy this? How can we avoid the pitfalls which so clearly lie ahead? Only, I believe, by retracing our steps and by joining forces with the agents of natural control—by working *with* natural forces rather than *against* them as we so obviously have been doing. We must change our philosophy, abandon our attitude of human superiority and admit that in many cases in natural environments we find ways and means of limiting populations of organisms in a more economical way than we can do it ourselves. In so doing, we also have to remember that we have increased the difficulties by our alteration of surroundings so that some extra help must often be given to overcome the new conditions in the environment. We must try to take care of the factors for which we ourselves are directly responsible and, in the process, avoid interfering with such working of natural control as may be observable.

For example, where a plant is grown in an area which is in some way unsuitable for it as a crop plant, we may have to control some adverse influence in order to insure its survival. Such a case would arise where a high humidity in the area renders

the plant susceptible to a fungus disease. This disease must be controlled, *i.e.*, the unsuitable condition must be compensated for by applying an appropriate treatment to the plant; but the treatment should be such that it does not interfere with the natural control of the insects inhabiting the plant environment. In such cases, the wrong treatment may cause outbreaks of certain pest species. For example, the use of mild sulphur sprays as a control for apple scab in the orchards of Nova Scotia gives rise to outbreaks of the oystershell scale and European red mite (Lord 1947).[1] Where these sprays are used, undue destruction of natural enemies which normally keep these species in check occurs. The use of comparatively harmless copper sprays for the same fungicidal purpose, however, allows the natural control factors to resume effective control.

The success which has attended the few serious attempts to carry out the principles of the basic idea of working with natural factors have given results which are sufficiently striking and encouraging to warrant the opinion that this must become the outlook of the future economic entomologist if mankind is to maintain his hold on an adequate food supply and therefore survive in the struggle for existence. I do not see how we can look to insecticides alone for the answer to our insect pest problems. Nor do I believe that natural control, alone, will always suffice to keep insects in check sufficiently for us to rely upon it to prevent economic damage to our crops under the artificial conditions under which they are grown. There are some cases, of course, where it may do so; but I am concerned here with generalities.

I do, however, look to the judicious use of artificial control measures as a *supplement* to natural control for the programmes of the future. Examples of the practical applixation of this conception are comparatively few in number but those of which we have a record have demonstrated beyond doubt, that due regard to the working of natural control pays dividends. We have the practical and successful results of several years' work by A. D. Pickett[2] and his staff on oystershell scale, European red mite and codling moth in the apple orchards of Nova Scotia as an example of this type of operation. Work on codling moth in South Africa has given similar excellent results following a predetermined plan of combined operations. Likewise, red scale of citrus, of which I spoke at a previous meeting (Ullyett 1948),[3] can be controlled largely by natural agents in the Transvaal and Cape Province groves provided the management of the orchards is based upon a knowledge of the environmental conditions. Here, fumigation and spraying, once looked upon as an annual necessity, are now regarded in the light of safeguards for abnormal seasons and for occasional use only as required by local circumstances.

In view of the information which we now possess, it seems clear that the time is ripe for a drastic revision of our outlook on pest control problems. As I see it, the aims of economic entomology in the future should be to develop insect control along the more rational lines indicated above; to make use of what we already find occurring in Nature and to supplement this only when and where it is clearly necessary to do so, To make this line of attack an efficient one, it will be necessary to increase our basic knowledge of natural environments, especially those of our crops and of the interrelationships existing between the various biotic and abiotic components of them. There is the need to look upon the environment and its inhabitants as a whole if we are to progress in this direction.

This "wholeness" of the environment becomes abundantly clear when we treat one part of it or direct our operations against a particular species of insect. In so doing we inevitably influence other parts or other species. In other words, we affect the whole and, in the process, often produce unexpected and often undesirable effects. Among the more striking of the recent examples of this is the almost invariable increase in mite populations on fruit trees following the application of DDT for the control of codling. There is the need for careful study in the field so that we may know where the natural control of pests is deficient under the conditions we have created and so that we may know where our own efforts should be applied for the most efficient results. There is the need for more knowledge of a detailed character of the effects of poisons, not only on the various insects

[1] Lord, F. T. 1947. Can. Ent. 79: 196–209.
[2] Pickett, A. D., N. A. Patterson, H. T. Stultz & F. T. Lord. 1946. Sci. Agric. 26: 590–600.
[3] Ullyett, G. C. 1948. JOUR. ECON. ENT. 41: 337–9.

and other arthropods but also upon the host-plants and upon the soil and its fauna, *i.e.*, upon the environment *as a whole.*

This outlook is essentially that of the ecologist. The development of work along these lines will therefore demand the attention of workers whose training and inclination are those of the insect ecologist. Economic entomology must become what it is now only in part, namely, applied insect ecology. In this there are boundless possibilities. The signs are promising; the benefits to be derived may be great. I am aware that the general acceptance of such an outlook will be opposed by obstacles of a forbidding nature. Prejudices of the "die-hards" must be met and overcome, growers convinced and a minor revolution must occur in the ranks of professional entomologists. The essentially long-term nature of most of the investigations concerned will be opposed by the demand for quick results by commercial interests. Furthermore, it will find opposition from the sales organizations of the vested interests.

Nevertheless, I look forward to the future when we shall see a more intelligent approach to our practical problems becoming the regular practice. Already we see, here and there, methods based upon sound information which are giving striking success. Already, growers who are following such programmes are finding a reduction in costs and an improvement in control. Let us therefore abandon the attempted conquest of the practically unattainable heights bearing the fetish of "100 percent mortality." Let us develop the habit of regarding ourselves dispassionately as biotic constituents of our environment and not as superior beings outside of it; and let us be content if we can assume the more natural role of *successful competitors* for the common food supply of the environment.

Possibilities for Better Citrus Insect Control Through the Study of the Ecological Effects of Spray Programs[1]

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During the past decade, there has been a tremendous increase in the use of chemicals for the control of insects and mites. Unfortunately, in many cases, the introduction of a new naterial has so upset the ecology of the insect fauna involved that the use of an additional pesticide has been necessitated. Perhaps the entomologist has too eagerly grasped the new tools produced by the agricultural chemist. Progress is questionable when the introduction of a new pesticide results in changing a relatively innocuous insect into a major pest problem. Pickett (1949) discussed this problem and suggested that the indiscriminate use of chemicals for the control of plant pests might well cause untold damage. The simple fact that a new compound kills a given insect more efficiently than another material should not be the only criterion for recommending its use. It is time that ecology be considered as an applied field, and time that a study be made of the many interactions that are taking place between insects, their diseases, parasites and predators, and the chemical means of control that are now employed.

In the course of this discussion the effects of some of the spray materials used on citrus in Florida will be described. Special emphasis will be given to their adverse effects upon control of the insect and mite populations which are present. In addition, the possibilities which exist in Florida for a reduction in the use of chemical control methods on citrus will be outlined. In order to understand fully the status of the use of sprays and dusts on citrus, some recent historical background is essential. About 1935 most citrus groves were suffering from malnutrition. At that time the basic fertilizer program was changed to include the use of magnesium, copper and manganese on the soil, and the use of copper and zinc as sprays. This resulted in more luxuriant foliage, larger trees, and heavier cropping. As the health and vigor of the trees increased, so increased the insect and mite problems. The

[1] Paper No. 4 of the Biological Control Symposium in Denver, 1950.

spray program which evolved includes in its present form not only the use of materials for the control of insects, mites, and diseases, but also the use of physiological sprays. In this latter category are found copper, zinc, and manganese as nutritional elements, and arsenic as a means of reducing the amount of acid in grapefruit. In addition to its nutritional characteristics, copper is also needed as a fungicide for the control of scab and melanose.[1] This spray program, as originally developed, was designed to produce a maximum amount of good quality fruit for the fresh fruit market.

During the past several years, more than 50 per cent of the total citrus crop in Florida has been canned. The fruit destined for the cannery does not require the high standards of external appearance needed for fresh fruit, but good internal quality is essential, and internal standards are often higher than for fresh fruit. As a result of this change in crop utilization, the present spray program is being re-examined to see if possibilities exist for a reduction in spray costs without attendant decreases in yield or internal fruit quality. This problem is now being attacked by studying the effect of individual sprays on the insects and mites present, on the general tree condition, and finally on the amount of fruit produced. In addition to these studies, the state has been divided into five districts with men working each district intensively, and keeping complete records of changes in insect and mite populations throughout the year (Pratt 1950). This work is being correlated with weather conditions and the presence or absence of diseases, parasites, and predators. It is hoped that these data will ultimately yield information on the normal and the expected behavior of citrus insect and mite populations. It is conceivable that out of this work may come not only more economical spray programs for cannery fruit, but also more efficient programs for fresh fruit. It is the adverse effect of spray materials upon the behavior of insect and mite populations as weighed against their beneficial effects which will ultimately determine the place of the various chemicals in any spray program in use.

EFFECTS FROM THE USE OF SPRAYS.—*Copper and Zinc.*—Copper is used as a spray both for nutritional purposes and as a control for melanose on the fruit. Its use may be eliminated if copper is included as a fertilizer amendment, and if melanose control is not desired. Thus, it will be feasible to leave it out of a cannery spray program. Zinc, on the other hand, is used to fulfill the needed zinc requirements of the tree. Soil applications of zinc were originally believed to be unsatisfactory, but recent observations indicate that it may be possible in many groves to maintain zinc nutritional requirements by using zinc as a soil amendment. Field observations do indicate that most groves can get along satisfactorily for from 1 to 3 years with no zinc sprays, and thus spraying may not be necessary every year. However, the minimal zinc requirement is a problem which must be fully investigated by horticulturists before definite recommendations can be made.

The spraying of either copper or zinc results in major changes in the insect and mite populations on citrus trees. Infestations of both purple and Florida red scales[2] are materially increased (Griffiths & Fisher 1950) They reach higher levels during the summer and remain at higher levels for a much longer period of tieme than do populations on unsprayed trees (Fig. 1). Both copper and zinc sprays have a fungicidal action on the entomogenous fungi which kill purple scale (Fisher 1950; Griffiths & Fisher 1950), and they probably have a similar effect upon the fungus diseases of both rust mites and citrus red mites[3] (Fisher 1950, 1951). In any case, both of these mites have abnormal population increases following the use of these spray materials (Thompson 1948) It is primarily the use of these two items in the spray program which necessitates regular applications of chemicals for the control of insect and mite pests. When copper and zinc sprays are eliminated, insect and mite damage is materially reduced.

Arsenic.—Lead arsenate is applied to grapefruit in order to produce a sweeter fruit. Its use results in earlier maturity, and therefore, the practice of applying arsenic to grapefruit is a common one. In the past, Florida red scale infestations have tended to be more severe on grape-

[1] *Elsinoe fawcetti* Bitanc. and Jenk., and *Diaporthe citri* Wolf, respectively.
[2] *Lepidosaphes beckii* (Newm.) and *Chrysomphalus aonidum* (L.), respectively.
[3] *Phyllocoptruta oleivora* (Ashm.), and *Paratetranychus citri* (McG.), respectively.

fruit trees where arsenic was used. This led to a belief that the presence of the arsenic caused the increase in this insect, and it was thought that this might be due to a reduction in predator insect populations. During the course of 3 years work, comparisons were made of both purple and Florida red scale control on trees where arsenic was included in the oil spray and where arsenic was not included. No differences were found in purple scale control. In fact, at times there appeared to be slightly better control on the arsenic sprayed trees. There was a tendency for Florida red scale populations to be higher on the plots where arsenic was applied, but these differences were not significant. The fact remains that in commercial groves Florida red scale infestations are definitely associated with the use of arsenic-oil sprays on grapefruit. In the past arsenic was usually applied with oil in late May or very early June, and sprays applied at this time are a month to 6 weeks too soon for maximum Florida red scale control. Thus, it is entirely possible that the timing of the arsenic-oil sprays may have been the only factor in increased red scale infestations. However, another explanation may lie in the fact that the inclusion of arsenic with its wetting agent may so change the character of the oil emulsion spray that less effective control would be obtained. Data from several years experience indicate that, although initial mortalities may not be as good when arsenic-oil sprays are used, 6 months later there may actually be less Florida red scale on these trees. In an attempt to explain this phenomenon, leaves from the same tree were segregated as to the presence or absence of arsenic toxicity symptoms. Arsenic toxicity results in a general yellowing of the leaf, so that it no longer has the shiny green appearance typical of citrus foliage. It was found that there were fewer scales on the arsenic toxic leaves than on the green foliage. This is in line with data previously presented by Thompson (1940) in which he showed that both magnesium and zinc deficient leaves had less scale per leaf than healthy green leaves on the same tree. The effects of arsenic on citrus insects is not altogether clear, but it is probable that it can be included in cannery spray programs with no major deleterious effect upon insect and mite control.

Sulfur.—Sulfur is used to control rust mites which cause a russetting of the fruit and "greasy spot" on the foliage (Thompson 1948). So far as is known russetting does not harm the internal quality. However, infestations of mites on the fruit shortly after the fruit is set may result in a decrease in the fruit size. Whether or not this will ultimately affect overall yield remains to be determined. "Greasy spot" so injures the leaves that they drop prematurely, and it may be that this severe leaf drop will result in decreased cropping. The use of sulfur causes increases in Florida red scale, purple scale, and citrus red mite (3,9,12) populations. Figure 2 shows the effects of sulfur sprays upon citrus red mite infestations as compared with a complete spray program (copper, zinc, DN, oil, sulfur) and an unsprayed control. In this experiment, the differential in mite populations could not be ex-

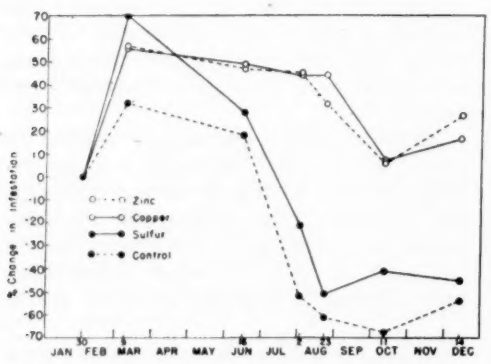

FIG. 1.—Changes in purple scale populations following the use of residue sprays in 1948 in a Pineapple orange block.

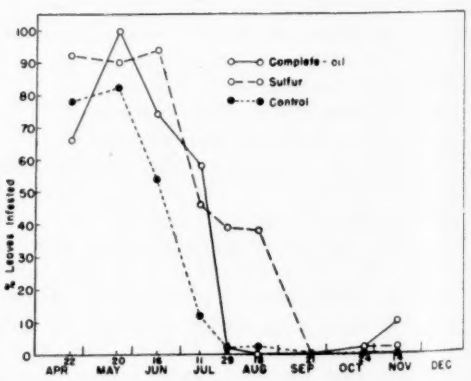

FIG. 2.—Changes in citrus red mite infestations on three different spray programs in 1950.

plained by any difference in the numbers of purple mite predators. The inclusion of sulfur in a cannery spray program will ultimately be determined by the balance of two factors: (1) the benefits derived by preventing early injury to fruit and by preventing leaf drop due to greasy spot, and (2) the damage done by increasing citrus red mite and scale infestations. Unpublished data by the author demonstrates that when sulfur treatment alone is compared with an unsprayed control, scalecides will be necessitated more often where the sulfur is used. Whether the cost of several sulfur applications can be justified by the benefits to be derived remains to be demonstrated.

Scalecides.—Both oil emulsion and parathion sprays are being used for scale control in Florida. Although field results in 1950 show some potential weaknesses of parathion, it is probable that parathion will ordinarily be a satisfactory replacement for oil. Oil sprays have never been shown to affect adversely the control of any insect or mite population on citrus, but they do materially affect tree condition. For the past 10 years, in two experimental blocks of grapefruit, unsprayed control trees have actually produced more fruit per tree per year than trees on a complete spray program. This differential is believed to exist because of the detrimental effects of oil sprays on tree vigor, and is present in spite of the fact that insect control and nutritional requirements were better on the sprayed trees. On other trees in the same block where only oil was left out of an otherwise complete spray program, injury due to scale reduced yield significantly. In an adjacent orange block this difference amounted to approximately 20 per cent of the entire crop (Thompson 1947). Parathion does not appear to damage the tree, although it has caused premature leaf drop in some instances. It is anticipated that the use of parathion as compared with oil for scale control may result in increased yields. Although the continued use of parathion has caused soft brown scale, *Coccus hesperidum* L. to become a severe problem on mature trees in a few commercial groves, no other deleterious effects have been noted to date.

DISCUSSION.—In order to grow citrus fruits for the fresh fruit market the external blemishes caused by melanose and rust mites must be controlled by the use of copper and sulfur. In addition to these materials, zinc is included in the spray program to prevent zinc deficiency, DN[1] for the control of citrus red mite, and oil or parathion for the control of scales. This spray program will produce fruit which has excellent quality, both internally and externally.

As contrasted with the above program, the grower who produces fruit for the cannery is concerned only with the maximum production of good internal quality fruit. Unless failure to use a given spray material results in inferior internal quality or decreased yield, there is no justification for its use. It is primarily the use of copper and zinc in the fresh fruit spray program which necessitates the regular use of other sprays. Copper can be eliminated in cannery programs and the amount and regularity of zinc sprays can be materially reduced in all probability. If it be assumed that copper andzinc sprays may be dispensed with, the problem revolves about insect and mite control only. Several alternatives may be suggested: (1) no sprays or dusts at all, (2) sulfur only for "greasy spot" control, (3) a scalecide only, or (4) sulfur for greasy spot control plus a scalecide. Whether oil or parathion would be preferred for scale control is dependent upon whether or not yield differences between these two sprays can be demonstrated. Control of citrus red mite may be necessary on occasion but with the elimination of zinc and copper this mite will probably not be a general problem. In any of these programs sprays should be used before scale or citrus red mite infestations cause serious damage, but the regular periodic control of most insects or mites would be limited.

During the past 3 years, field scale trials on Valencia oranges and seedy grapefruit have been in progress. These experiments are designed to determine if unsprayed groves can produce as much fruit as a grove on a complete spray program. In addition, a sulfur dust program has been included on which rust mite injury to fruit is prevented. In 3 years, the following results have been obtained: (1) there have been no significant yield differences,[1] (2) there have been no significant differences in internal quality, (3) zinc deficiency has

[1] 40 per cent dinitro-o-cyclohexyl phenol for citrus red mite control, and oil or parathion for scale control.

not been a problem, (4) scales and citrus red mites have been less prevelent on the unsprayed plots, and (5) during the third year some of the sulfur dust plots required the application of a scalecide. Experimental plots involving scale control only and greasy spot control only have been instituted during 1950, but it is, of course, too soon to have results from these plots.

On the basis of the above results, it would appear that reduced spray programs are definitely feasible for the production of cannery fruit. There is much to be learned about the effects of spray materials upon the pests themselves and upon their diseases, parasites, and predators. When these facts have been determined, real progress can be made in determining just what spray materials to use and the optimum time when to apply them.

SUMMARY AND CONCLUSIONS.—The effects of the use of copper, zinc, arsenic, sulfur, oil, and parathion upon citrus insects and mites are discussed. The use of copper and zinc results in definite increases in citrus rust mite, citrus red mite, purple scale and Florida red scale populations. There is a good possibility that fruit which is to be canned may be grown with a considerable reduction in the cost of spray programs without sacrificing the benefits of maximum yields.

[1] Valencia yields based on 2 years only.

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DUDLEY MOULTON

Dudley Moulton, former Agricultural Commissioner of San Francisco County, former Director of the California State Department of Agriculture, and a well known specialist on Thysanoptera, died in San Gabriel, California, on July 5, 1951. Since 1948 he has lived at 815 Santa Ynez St., in San Gabriel. A more extended account of Dr. Moulton's life and activities will be published in a later issue of the *Journal.*

Chemical Activity Ratios in Relation to Species-Specificity

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It has been reported previously (Beard 1949) that differences among insects in susceptibility to toxicants are greater than can be explained by differences in effective routes of administration. In other words, gross morphological barriers which might prevent toxicants from reaching their sites of action cannot explain, alone, species-specificity. This suggests that mode of action, as well as site of action, might be involved. In view of this, tests were made to determine if a series of toxicants having (presumably) the same mode of action would have the same proportionate effect on two unrelated insects. The hypothesis to be tested is a simple one (Fig. 1). It might be assumed that two different insects could have different quantities of the sensitive substrate upon which the toxicant acts and so would require different quantities of the toxicant to be affected; but different toxicants might maintain a constant ratio of effectiveness in terms of the two insects, even though the different toxicants were not equally active against the common substrate.

In testing this hypothesis, two procedures were followed. In one case eserine and a series of organic phosphorous compounds, which are inhibitors of cholinesterase (Metcalf & March 1949), were observed for toxic effects against *Oncopeltus* (milkweed bug) adults and *Galleria* (wax moth) larvae. In the other case, the darkening of hemolymph upon exposure to air, presumably representing the action of tyrosinase upon tyrosine, was observed in *Galleria* and *Popillia* (Japanese Beetle) larvae, using a series of compounds as inhibitors.

Mortality as a criterion for toxic action is somewhat less enlightening than criteria based on direct study of the vulnerable system, but the organic phosphorous compounds are presumed to be toxic by virtue of their anti-cholinesterase activity. That this is the only mode of toxic action, however, has not been proved. Nevertheless, mortality studies were made using the test compounds in solutions of olive oil injected parenterally into *Oncopeltus* adults and *Galleria* larvae by the technique described in a previous paper (Beard 1949). The LD_{50} for each compound was estimated, and the ratio of the LD^{50} for *Galleria* to the LD-50 for *Oncopeltus* was found to be as indicated in table 1.

Table 1.—Toxicity ratios of anti-cholinesterases

	LD_{50} *Galleria* / LD_{50} *Oncopeltus*
Eserine	1
Parathion	11
Hexaethyl tetraphosphate	20
Tetraethyl pyrophosphate	30
Tetraethyl dithiono pyrophosphate	9
Tetraethyl monothiono pyrophosphate	60

These data are based on dosage response curves drawn by eye and not subjected to the statistical refinement of equating replicates and applying the appropriate weights and corrections. Consequently these ratios must be considered estimates lacking in some precision, but the differences in activity ratios are too great to permit any conclusion other than that some chemicals acting on the same physiological system do not necessarily affect different insects in proportionate degrees. This is confirmed by data of Metcalf & March (1949) who determined the toxicity of a series of phosphate compounds to the worker honeybee and the housefly. Calculation of some of their data in terms of the ratio of the LD_{50} for the honeybee to the LD_{50} for the housefly yields the values listed in table 2.

Again the differences are wide, but it will be noted that a single compound, diisopropyl *p*-nitrophenyl thiophosphate, accounts

Table 2.—Toxicity ratios of anti-cholinesterases. (Calculated from data of Metcalf & March.)

	LD_{50} HONEYBEE / LD_{50} HOUSEFLY
diethyl *p*-nitrophenyl phosphate	1.2
diethyl *p*-nitrophenyl thiophosphate	4.
dimethyl *p*-nitrophenyl phosphate	0.3
dimethyl *p*-nitrophenyl thiophosphate	1.7
diisopropyl *p*-nitrophenyl phosphate	0.5
diisopropyl *p*-nitrophenyl thiophosphate	250.
dipropyl *p*-nitrophenyl thiophosphate	7.5
ethyl, butyl *p*-nitrophenyl thiophosphate	2.

Table 3.—Ratios of effectiveness of tyrosinase inhibitors.

	Quantity of Inhibitor Required for *Galleria* Blood / Quantity of Inhibitor Required for *Popillia* Blood
Thiourea	6
Phenylthiourea	1300
Allylthiourea	4
Thioacetanilide	100
Thioacetamide	4
Sodium azide	50
Sodium thioglycollate	1

for the greatest difference. Conceivably this compound acts on an additional system in the housefly, or the honeybee has a protective mechanism against this compound that the fly does not possess. Even without this chemical, however, the ratios are not constant.

Such observations as these, in which the intact organism is considered, and which indicate that toxicants acting on the same physiological system do not maintain a constant ratio of effectiveness in terms of two insects, may be explained on the basis that the insects differ in their respective abilities to detoxify or eliminate the different chemicals. To avoid the elimination factor, the melanization of blood withdrawn from *Galleria* larvae and *Popillia* larvae was observed as affected by a series of inhibitors.

The blackening of insect blood exposed to air can be inhibited by thiourea and several related compounds. Although the decrease in blackening is not a reliable index of the actual inhibitory action of a compound, it appears suitable for a comparative test. The technique employed was to impregnate filter paper with the desired concentration of the test chemical, that is, with the given quantity of inhibitor per unit area of paper. A drop of larval blood was applied to the filter paper, which was then placed in a moist chamber. After a uniform time interval (one hour) the color of the blood was compared with a series of standards, and the degree of inhibition was estimated on the basis of uninhibited controls. Six estimates were made for each concentration of each chemical. The mean score was plotted on log-probit paper, regression lines plotted by eye, and the ED_{50} estimated by inspection. From these data the ratio of the quantity of inhibitor required for *Galleria* blood to the quantity of inhibitor required for *Popillia* blood was calculated to be as indicated in table 3.

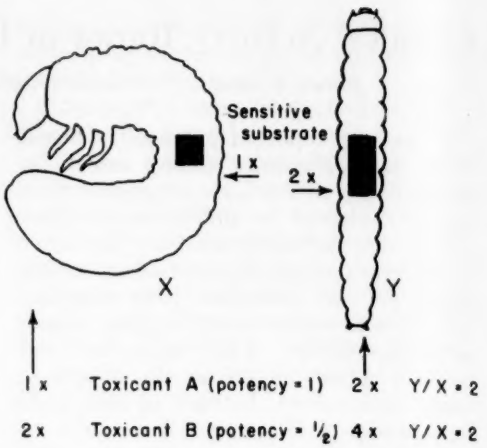

FIG. 1.—Hypothetical quantitative relationships of two chemicals, differing in potency, acting on a common substrate in two different insects, and exhibiting the activity ratio of Y/X.

Wide differences in these ratios attest the conclusion that more is involved in species-specificity than specific differences in the quantity of the vulnerable substrate and the ease with which a toxicant reaches the site of action. This has the important implication that increasing the permeability of a insecticide will not necessarily, and by itself, render that insecticide effective against those insects which are hard to kill

The explanation of species-specificity at such fundamental levels may be found among several considerations. Not only may the vulnerable substrates be qualitatively as well as quantitatively different in the insects tested, but the different inhibitors chosen may act directly or indirectly on the substrate, depending upon the chemical complex associated with the substrate. These different chemical complexes may themselves constitute differential antagonistic systems against the test compounds. Whatever the explanation may be, the conclusions, if found to be generally true for other physiological systems, render highly improbable the finding of a chemical which is highly toxic to all insects, but nontoxic to higher animals. On the other hand, the conclusions

bear out the possibility of selective insecticides.

SUMMARY.—Tests were made to determine if a series of chemicals having the same mode of action would have the same proportionate effect on two unrelated insects. Chemicals having anti-cholinesterase effects were tested for toxicity. Chemicals having anti-tyrosinase activity were tested for inhibition of hemolymph melanization. Results showed that the effects were disproportionate within the chemical series and hence indicated species-specificity at fundamental levels.

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Studies on Treatment of Flies With Radioactive Phosphorus[1,2,3]

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Studies on the possible use of radioactive phosphorus (P^{32}) as a means of tagging flies for flight studies were begun at Corvallis, Oreg., in August 1949. The primary purposes of the investigation were to establish whether this isotope could be incorporated in the insects and detected after an elapse of time and to develop methods by which the insect could obtain a detectable amount of the radioactive material. In addition, the effect of large dosages on egg production or fertility and the possibility of obtaining lethal mutations were explored.

Two methods of introducing the P^{32} isotope into the flies were tried, feeding them aqueous solutions of radioactive phosphoric acid and rearing them in media to which this material had been added. Radio activity of the flies was measured with a thin-walled (1.85 mg./cm.^{2}) Geiger-Müller tube attached to a commercial-model 64 scaler. The flies were placed individually in 1-inch metal counting dishes and the tops were covered with scotch tape. All counts recorded were above background.

PRELIMINARY TESTS.—The first tests were conducted with house flies, *Musca domestica* L. Radioactivity measurements on flies that had fed on 10 per cent sugar solutions containing small but undetermined quantities of radioactive phosphoric acid gave readings of 3000 to 4000 counts per minute (c.p.m.). Flies reared from larvae in media containing radioactive phosphoric acid were also found to be appreciably radioactive. These crude tests were sufficient to establish that house flies could obtain detectable amounts of P^{32} by feeding upon or being reared in a medium containing P^{32} and that the isotope did not visibly injure the insect.

Selected examples of these preliminary tests with house flies are summarized in table 1. Post-dissection counts are also given to illustrate the distribution of the radioactive isotope in the component parts. It may be seen that the percentage of P^{32} present in each component is similar whether the fly was fed the isotope or was reared in a medium containing it.

In conjunction with these tests other house flies were fed larger quantities of P^{32} to determine whether the isotope would be carried through to the following generation. These flies gave readings up to 100,000 c.p.m. Flies giving 70,000 to 100,000 c.p.m. produced few viable eggs. Flies reared from these eggs either did not oviposit or their eggs did not produce larvae. In a few tests the eggs from flies giving 5000 to 8500 c.p.m. carried a small part of the isotope, from 5 to 32 c.p.m., into the next generation.

A few tests were conducted with the blow fly, *Phaenicia sericata* (Meig). When larvae were reared in a ground-beef medium to which P^{32} had been added,

[1] This research was supported in part by the Atomic Energy Commission under a contract administered by the Office of Naval Research to Oregon State College.

[2] Published as Technical Paper No. 645 with the approval of the Director of the Oregon Agricultural Experiment Station. Contribution of the Department of Agricultural Chemistry.

[3] Presented at the Pacific Slope Branch meetings of the American Association of Economic Entomologists at Santa Cruz, Calif., June 14–16, 1950.

measurable quantities of the isotope were found in the flies that emerged several days later. This blow fly also fed readily on sugar solutions containing radioactive phosphoric acid. Closely related to *Phaenicia sericata* is the screw-worm fly, *Callitroga ameriacana* (C. and p.), a severe pest of livestock in the southern United States. Information is needed on the flight and migration of this fly, and the results obtained with *Phaenicia* indicate that screw-worm flies could also be tagged with P^{32} by feeding them radioactive material.

TESTS WITH DEFINITE DOSAGES OF P^{32}.—A second sample of radioactive phosphoric acid became available in December 1949 and was used in tests to learn the effect of different known dosages. This sample was removed from the pile on December 12; however, dosages were calculated from December 15, the date the sample was received. All dosages used after December 15 were corrected for decay of the P^{32}. No correction was made for decay from the time treatment was applied to the insects and subsequent testing for radioactivity.

FEEDING TESTS.—Four groups of day-old house flies were placed in small screen cages and fed sugar solutions containing radioactive phosphoric acid according to the following plan:

GROUP	NUMBER OF FLIES		P^{32} FED (μc.)
	Females	Males	
A	10	10	120
B	10	10	20
C	10		60
D		10	60

One of these solutions in a small petri dish was placed in each cage and distilled water was added daily to compensate for evaporation. The flies fed avidly.

After 4 days the flies from groups A and B were paired . . . *i. e.*, one male and one female from the same cage . . . and the pairs removed to individual cages. Each female from group C was paired with an untreated male from the regular laboratory colony, and the males from cage D were paired with untreated virgin females. One egg mass containing from 100 to 200 eggs was obtained from each surviving female in all groups except C, where only one of the females oviposited.

After the eggs had been obtained, radioactivity of the females was measured and attempts were made to rear flies from the eggs.

The females in group A averaged 95,426 c.p.m. 7 days after the test was started. Although all these females oviposited, no larvae were obtained from the eggs.

The nine group-B females that lived to lay eggs averaged 21,744 c.p.m., and 4 of the egg masses produced one or more larvae each. Only 14 pupae were obtained, but from 11 of these pupae flies that averaged 22 c.p.m. emerged 28 days after the parents had fed on the radioactive solution.

From the one female in group C that deposited eggs 43 pupae developed, and 42 flies emerged. The F_1 and F_2 generations of this group produced normal numbers of eggs and hatching was normal.

The males in group D averaged 37,932 c.p.m. All the untreated females that had

Table 1.—Distribution of radioactive phosphorus in house flies administered radioactive phosphoric acid.

PART EXAMINED	FEEDING TESTS				REARING TESTS			
	No. 37		No. 38		No. 34		No. 35	
	C.p.m.	Per Cent of Total	C.p.m.	Per Cent of Total	C.p.m.	Per Cent of Total	C.p.m.	Per Cent of Total
House fly before dissection	3527	—	3194	—	408	—	834	—
Part of body after dissection:								
Head	234	5.8	174	5.5	37	7.8	81	8.2
Thorax	784	19.4	892	28.0	125	26.5	296	29.9
Abdomen	2745	67.8	1996	62.5	270	57.2	554	56.0
Legs	256	6.3	120	3.7	36	7.6	52	5.2
Wings	28	0.7	11	0.3	4	0.7	7	0.7
Total	4047	100	3193	100	472	100	990	100

mated with these males oviposited and a total of 208 pupae were obtained.

The entire experiment was repeated with lower dosages of P^{32} and results were in general similar to those recorded here.

REARING TESTS.—In these tests 50 grams of dry, standard NAIDM rearing medium was weighed out into each of five 250-ml. beakers, and in four beakers sufficient radioactive phosphoric acid solution was introduced to give 2.4, 1.6, 0.8, and 0.4 μc. of P^{32} per gram of medium; the fifth beaker was left untreated for use as a check. House fly eggs from the laboratory colony were then placed into each beaker.

The larvae developed normally in all beakers, pupae formed, and adults emerged from the treated and untreated media simultaneously. Radioactivity measurements on the pupae and adults are presented in table 2. The counts were roughly proportionate to the concentration of P^{32} in the medium in which the flies were reared. The pupae gave much higher counts than the adults.

Table 2.—Radioactivity of house fly pupae and adults reared in media to which different amounts of radioactive phosphoric acid has been added. Counts are averages for six flies. Eggs placed in medium January 12, 1950. Decay not computed.

STAGE	DATE OF COUNTS (1950)	COUNTS PER MINUTE FOR FLIES EXPOSED TO INDICATED AMOUNT OF P^{32}			
		2.4 μc.	1.6 μc.	0.8 μc.	0.4 μc.
Pupae	Jan. 25	6738	4419	1356	1377
Adults	Feb. 1	3168	2900	—	837

In the course of radioactivity measurements of adult flies at the time of emergence it was found that some of the radioactive material remained in the empty puparia after the flies emerged. As an example, one fly reared in a medium containing 0.8 μc. per gram had a count of 1578 and the empty pupal case a count of 368.

No abnormalities were observed in any stage of house flies reared in radioactive media. Adults of the F_1 generation appeared normal and produced a normal complement of viable eggs. Flies reared in media containing 2.4 and 0.8 μc. of radioactive phosphorus per gram were carried to the F_3 generation without observed mutants. Blumel (1950) found that several mutations of *Drosophila virilis* (Sturt.) were produced when this fly was reared in a medium containing 16.5 μc. of radioactive phosphorus per milliliter.

CONCLUSION.—For use in certain types of studies on the biology and control of house flies and blow flies the easiest and most economical method of introducing the radioactive phosphorus into the insect is by feeding the adults solutions of radioactive phosphoric acid. The data, although limited, indicate that by this method 1 millicurie (1000 μc.) of P^{32} could be expected to treat 20,000 house flies, giving good radioactivity per fly several days after the feeding. By the rearing method the same concentration could be expected to treat 5000 house flies to the same radioactivity per fly. A fly reared in or fed radioactive P^{32} does not appear to be injured outwardly, but it is indicated that a reduction of fertility may develop when large amounts (70,000 to 100,000 μc.) of the radioactive material are absorbed or ingested.

SUMMARY.—In 1949 studies on the treatment of house flies, *Musca domestica* L., with radioactive phosphorus (P^{32}) were undertaken at Corvallis, Oreg., to determine its possibilities as a means of tagging flies for flight studies, and also to learn the effect on egg production and subsequent generations of flies. A few tests were also conducted with the blow fly *Phaenicia sericata* (Meig.). The flies were either fed sugar solutions of radioactive phosphoric acid or reared in a medium containing this radioactive material.

In the preliminary tests flies were made radioactive by both feeding and rearing, the treatment had some effect on fertility, and when large dosages were fed some radioactivity was carried over into the next generation.

Subsequent tests with known amounts of P^{32} supported the results. Feeding tests indicated that fertility was adversely affected in rearing tests did not appear to alter fertility. It was also indicated that feeding adult flies a solution containing radioactive phosphorus was the more economical and efficient method of tagging with P^{32}.

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Joint Toxic Action Against House Flies in Mixtures of Parathion and Its Methyl Homolog

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Among the compounds produced to replace or supplement parathion as an insecticide is its methyl homolog, O,O-dimethyl O-*p*-nitrophenyl thiophosphate. The possibility has been mentioned that this homolog may be less hazardous to apply than parathion (Hall 1950). However, because the acute oral toxicity of all the known organic phosphate insecticides, including the methyl homolog, falls within the range of 5–30 mg. per kilogram for rats Lehman (1950) states that they should be placed in the same category as parathion in so far as the operational hazards are concerned. He reports, nevertheless, that the dermal toxicity of the methyl homolog appears to be about one-tenth that of other new organic phosphate insecticides. It has been reported privately from Denmark[1] that a 2:1 mixture of the methyl homolog and parathion containing an emulsifier was at least as effective as parathion against insects, but only about one-half to one-third as toxic to rabbits when administered orally. It has also been suggested that the joint insecticidal action of mixtures of parathion and its methyl homolog is of the synergistic type.

A study was undertaken to obtain such information on the relative toxicity to an insect of the two compounds and mixtures of them as to permit the identification of the type of joint action concerned.

Materials.—Chemically pure samples of the two compounds[2] were used, the melting point of the parathion being 6° C. and that of the methyl homolog 35°. Sprays were prepared by incorporating the compounds in refined kerosene. A series of concentrations was selected, according to preliminary tests, so that a wide range of mortalities would be obtained for each compound and for three mixtures of the two.

Procedure.—Evaluation of the toxicity of these sprays was made against laboratory-reared adult house flies, *Musca domestica* L., by the Campbell turntable method. Knockdown and mortality were measured in replicated tests, all the sprays being tested once on each of eight populations of flies. Approximately 100 flies, averaging 3 days in age, were used in each test.

Results.—Knockdown of flies in 25 minutes was very low with all sprays; in no case was it higher than 10 per cent.

The mortality data are summarized in table 1. Methods of probit analysis described by Finney (1947) were used to obtain regression lines from these data and to estimate the LC 50 and its standard error for each of the compounds and mixtures. The equations for the lines showing the relationship between the transformed functions of the variates, probits, and logarithms of concentrations in micrograms per milliliter are as follows:

Parathion	$Y=-4.324+5.197X$
Methyl homolog	$Y=-5.194+5.197X$
Parathion-homolog mixtures:	
1:4	$Y=-5.054+5.197X$
1:1	$Y=-4.616+5.197X$
4:1	$Y=-4.550+5.197X$

The regression coefficients of the individually determined provisional lines show that the lines are essentially parallel; they were respectively, 5.59, 5.32, 4.92, 5.13, and 5.38 probits per unit log concentration for the five materials. In the statistical analysis no evidence was found of a conflict with the hypothesis that the five lines are parallel; therefore, the fitting of parallel lines as shown by the above equations was justified. Estimations from this study of the data are given in table 2.

Discussion.—Three types of joint action have been recognized by Bliss (1939) and Finney (1947)—independent, similar, and synergistic.

In independent action the toxicity of the mixture can be predicted from the individual action of each constituent by the simple combination of two independent probabilities. In similar action one component can be substituted for any proportion of the other at a constant ratio without altering the toxicity of the com-

[1] By Knud Christensen of Copenhagen.
[2] Obtained from S. A. Hall, of this Bureau.

Table 1.—Mortality of house flies caused by parathion, its methyl homolog, and mixtures of the two materials in oil sprays.

Material	Concentration (Micrograms per Milliliter)	Per Cent Mortality in 1 Day
Parathion	133	95.2
	100	87.9
	75.0	73.2
	56.3	37.2
	42.2	14.1
Methyl homolog	178	95.9
	133	73.4
	100	55.9
	75.0	40.4
	56.3	12.5
Parathion-homolog mixtures:		
1:4	133	82.7
	100	66.3
	75.0	31.6
	56.3	21.0
1:1	133	94.5
	100	72.2
	75.0	53.1
	56.3	30.0
4:1	133	92.9
	100	83.6
	75.0	55.7
	56.3	31.1

bination.. Toxic mixtures showing this type of action have a greater expected potency than those showing independent action. When synergism occurs, the toxicity of the mixture is greater than that which may be expected from the individual toxicities of the two components.

A fourth type, antagonism, has been described by Clark (1933) and was also briefly discussed by Bliss and by Finney. This may be considered as an effect opposite to that of synergism, since the toxicity of the mixture is lower than would be expected from the individual action of the components. Because the action may be treated as negative synergism, mathematical recognition and measurement of it would be made in the method applicable to that type of action.

The mortality data in table 1 indicate that the joint action of the two toxicants in mixtures is neither of the independent type nor of a pronouncedly synergistic type. Observed mortalities for the mixtures are so high that the former cannot apply. They fall between those obtained with individual toxicants, the toxicities of which are not greatly different, so that synergism cannot be pronounced.

The combined effect of two toxicants acting independently is examined most readily in terms of mortalities. If the doses of two toxicants are capable of causing mortalities of P_1 and P_2 when used separately the simplest expression of an expected total mortality when the two materials are combined and they act independently is $P = P_1 + P_2(1 - P_1)$. This is the expression for action without correlation in susceptibility to the two components. The expected mortalities on the basis of this expression, calculated for each of the mixed sprays, are given in table 3. The observed mortalities are much too great as compared with these figures for the joint action to be of the independent type. With correlation in susceptibility the differences would be even greater.

The estimates given in table 2 show

Table 2.—Relative toxicity to house flies of parathion, its methyl homolog, and three mixtures of the two materials.

Material	LC 50 (Micrograms per Milliliter)			Ratio of Toxicity to That of Parathion			Log of Ratio of Equivalents	Log Required for Significance
	Original Basis	Expected for Similar Action	Parathion Equivalent	Original Basis	Expected for Similar Action	Parathion Equivalent		
Parathion	62.3±0.6	—	62.3	1.0	—	1.0	—	—
Methyl homolog	91.5±1.0	—	62.3	0.681	—	1.0	—	—
Parathion-homolog mixtures:								
1:4	86.0±1.0	83.6	64.1	0.724	0.745	0.972	−0.012	0.019
1:1	70.9±1.0	74.1	59.6	0.879	0.841	1.044	0.019	0.022
4:1	68.8±0.8	66.5	64.4	0.906	0.937	0.967	−0.015	0.020

Table 3.—Comparison of observed mortalities of the mixtures of parathion and its methyl homolog with expected mortalities for two types of joint action.

Parathion-Homolog Mixture	Concentration (Micrograms per Milliliter)		Per Cent Mortality in 1 Day		
	Parathion	Methyl Homolog	Observed	Expected for Independent Action	Expected for Similar Action
1:4	26.7	106.7	82.7±4.5	64.5	85.4
	20.0	80.0	66.3±5.6	38.4	65.7
	15.0	60.0	31.6±5.5	17.1	40.3
	11.3	45.0	21.0±4.8	5.5	18.6
1:1	66.7	66.7	94.5±2.7	66.5	90.8
	50.0	50.0	72.2±5.3	36.9	75.0
	37.5	37.5	53.1±5.9	14.5	51.0
	28.1	28.1	30.0±5.4	4.0	26.6
4:1	106.7	26.7	92.9±3.1	88.8	94.2
	80.0	20.0	83.6±4.4	71.4	82.1
	60.0	15.0	55.7±5.9	46.7	60.6
	45.0	11.3	31.1±5.5	23.2	35.3

that neither synergism nor antagonism has been demonstrated in the mixtures. They also show that the joint action is not significantly different from similarity.

To show how well the observed mortalities throughout the course of action agree with those to be expected for similar action, the latter were calculated and are also given in table 3. Since equations with the generalized regression coefficient are used, these values are the same whether calculated from equivalents referred to the parathion line or the homolog line.

The standard errors of the observed mean mortalities were estimated from an analysis of variance of all the individual observations, the mortalities being transformed to angles of equal information (Bliss 1938).

For the 12 mixed sprays not one of the mortalities expected for similar action differed significantly from the means of the observed mortalities.

Therefore, under the conditions of these tests one toxicant can be substituted for the other at a constant proportion as indicated by their relative toxicity; the toxicity of a mixture of the two is predictable directly from that of either of the compounds alone if their proportions in the mixture are known.

SUMMARY.—The relative toxicity to adult house flies, *Musca domestica* L., of parathion, its methyl homolog, and three mixtures of these compounds was determined by the turntable method.

The methyl homolog was 68 per cent as toxic as parathion. The mixtures of parathion and its methyl homolog (1:4, 1:1, and 4:1) were, respectively, 72, 88, and 91 per cent as toxic as parathion.

The action of the compounds when applied jointly was identified as similar action since one of them can be substituted for the other in a constant ratio without altering the toxicity of the mixture.

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An Increase in the Duration of the Life Cycle of DDT-Resistant Strains of the House Fly

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Since the appearance of DDT-resistant house flies in New York dairy barns during the summer of 1948, studies on resistant strains have been made in the laboratory and field. The laboratory studies were designed to provide guidance in the planning and interpretation of the field experiments. Observations made in connection with this work indicated that the life cycle of a DDT-resistant strain of flies was longer than a strain having no abnormal resistance to DDT. Subsequent observations with other DDT-resistant strains substantiated this observation and led to a study of the life history of house flies having varying levels of DDT resistance.

Published data on the life history of insecticide-resistant house flies are few and somewhat contradictory. Barber *et al.* (1948) developed strains of flies that by the second generation, were resistant to DDT, pyrethrins, and an unnamed botanical extract. The pupae of these resistant strains were somewhat larger than those of the non-resistant flies. March & Metcalf (1950) however, cited the results of work in which there was no statistical difference in the length of life cycle, average weight of individual flies, or in the susceptibility to immobiliazation by heat and cold between DDT-resistant and non-resistant strains.

ORIGIN AND MAINTENANCE OF STRAINS.—When this study was undertaken, the resistant strains on which the preliminary observations had been made were no longer available. As a result it was decided to compare a strain having no abnormal resistance to DDT with a strain highly resistant to DDT. After a difference was found between these two strains, other strains of house flies were compared to determine if the differences were because of some peculiarity of the two strains or if the findings held for other strains in the field.

The non-resistant strain was obtained from the Geigy Company early in 1949 and was maintained without exposure to insecticides in the Cornell insectary.

To obtain a strain of flies highly resistant to DDT, flies were collected in September, 1949 from a Tompkins County dairy barn which had shown unsatisfactory control when it had been treated the previous June with a spray containing 60 pounds of 50 per cent DDT wettable powder in 100 gallons of water. The flies were brought into the laboratory and designated as strain "A". To increase the level of resistance of this strain, 20,000 flies from each of five successive generations were exposed in cages treated with 4,000 mg of DDT per sq. ft. until 97 to 99 per cent were knocked down. The survivors were used as breeding stock. All the flies emerging in each generation within a 24 hour period were held an additional 24 hours before exposure in the treated cages. After passing through the fifth generation the KD-50 for resistant strain "A" was at least 10,000 times that of the non-resistant strain and the life history study was started. At this time, approximately 3 per cent of the flies could survive an exposure of 2.5 weeks on a deposit of 4,000 mg. of DDT per square foot.

Three additional strains of DDT-resistant flies were collected in June, 1950 from three leading dairy counties in different sections of the state; DDT-resistant strain "H" from Cortland County; "O" from Delaware County; and "W" from Jefferson County. In each county, approximately 100 flies were taken from each of six widely scattered barns and combined to make a representative, but heterogeneous, strain from the county. After these strains had passed through two generations without treatment in the laboratory, eggs were obtained from each for the tests on the length of larval period and level of resistance of the adult flies to DDT.

The larvae of all strains were reared in the standard N A I D M medium and the adult flies were fed a solution of equal parts of water and milk. Three rooms having a mean temperature of 83° F. plus or minus 4° F. were used for rearing.

[1] The authors wish to acknowledge the able assistance of R. G. Blenk and C. E. Dasch in rearing the house fly strains used in this investigation.

EASTERN BRANCH PROGRAM, 1950.

MEASUREMENT OF RESISTANCE.—Aerosol grade DDT (S. P. not less than 103° C.) was used in the toxicity tests to measure the level of DDT resistance of all the strains studied and to build up the resistance of strain "A". A stock solution containing 10 per cent DDT, 80 per cent xylene, and 10 per cent emulsifier[1] was used and diluted with water to make the desired concentration to determine the resistance of all the strains except strain "A". Because of the high resistance of strain "A", a 30 per cent DDT, 70 per cent acetone solution was used undiluted. All treatments were applied with a spray gun[2] which was operated at 15 pounds air pressure as the cages passed through a spray cone on a constant speed treadmill. The test cages were sprayed only once, but the cages used for developing the resistant strain "A" were sprayed several times to obtain the desired deposit.

All cages used were constructed from galvanized wire screen 18 by 14 meshes per sq. in. The test cages used in measuring the level of resistance to DDT were 5 inches high and 2.5 inches in diameter.

Table 1.—The susceptibility to DDT of several strains of house flies on which life history studies were made.

STRAIN	PER CENT CONCENTRATION OF DDT ON SCREEN TO PRODUCE A KD-50 IN 12 HOURS	
	Male	Female
Non-resistant	.098	.20
DDT-resistant "O"	.58	2.4
DDT-resistant "H"	1.5	4.4
DDT-resistant "W"	1.5	4.5
DDT-resistant "A"	30.[1]	30.[2]

[1] 3 per cent knockdown in 12 hours.
[2] 0 per cent knockdown in 12 hours.

The cages used to maintain and build up the resistance in the DDT-resistant strain "A" were 12 inches high and 6 inches in diameter.

The flies used in the study of the level of resistance were obtained from the same generation as those used in making the life history studies. The flies emerging within a 24 hour period were held 2 days before they were exposed in the test cages. Flies from larvae which pupated first through to last in the larval population were tested for each strain to obtain results representative of the whole population. Ten replicates of about 100 flies each for every strain were exposed to each of 5 concentrations of DDT for 12 hours. At the end of the 12 hour exposure period all the flies knocked down or dead were removed, and the unaffected flies were killed. Both groups were counted and sexed to determine the resistance of each sex. The per cent mortality for each concentration was then plotted on log probability paper and the concentration necessary to produce a KD-50 estimated. The per cent concentration of DDT producing a KD-50 in 12 hours for each sex and strain is presented in table 1.

LIFE HISTORY OBSERVATIONS.—The data obtained from the life history studies were compared statistically using Student's method with argument "t" from Snedecor (1946).

Egg stage—The percentage and time of hatching for the nonresistant strain and DDT-resistant strain "A" was determined. For both strains, 100 eggs laid within a one hour period were placed in each of four petri dishes. The bottom of each dish was lined with dampened blue paper to maintain the humidity at a satisfactory level and to provide a dark background for observing the light eggs.

The peak of hatching occurred at the eleventh hour for both strains. The eggs began hatching at the tenth hour and no eggs hatched after the twelveth hour. The percentage of eggs hatching for the nonresistant strain was 99.5 per cent, and for DDT-resistant strain "A" 99.7 per cent. The differences between the two strains either in the time of hatching or the percentage hatching were not statistically significant.

LARVAL STAGE.—All strains described were used in this portion of the study. For each strain 250 eggs laid within a one hour period were placed in each of five 1-quart rearing jars. When the larvae were 3.5 days old (just before pupation started) the dry top medium was removed from the rearing jars. A dry pad of cheesecloth was placed over the wet medium to provide a pupation site. The pad was removed every 12 hours and replaced with another pad. Larvae pupating within each 12 hour period were removed and counted throughout the pupation period. The period of time after the eggs hatched to the time the

[1] *Triton X-100.*
[2] DeVilbis gun, Type CH, nozzle No. 92.

larvae pupated was considered the larval period. The percentages of the total larval population pupating are plotted for each 12 hour period (Fig. 1). The individual curves for strains "H" and "W" were not identical, but were so similar that one curve has been used to represent them. The "sawtooth" effect of the curves is caused by the heavier pupation during the dark than in the light. All the peaks do not occur at the same time because they were not all started at the same time of day.

Significant differences were found between all strains except the DDT-resistant strains "H" and "W" , both in the time at which peak pupation occurred and in the span of time required for all of the larvae to pupate. These differences in the length of the larval period were found to be statistically significant at the 1 per cent level. Observations made on later generations of the nonresistant and strain "A" larvae, showed the length of larval period to vary but slightly from the data presented.

A comparison of table 1 and Fig. 1 shows a close relationship between the level of DDT resistance and the duration of the larval period. In each case, with an increase in the level of DDT resistance there was an increase in the length of the larval period. When the levels of resistance were the same (strains "H" and "W"), the length of the larval period was found to be the same.

The close relation between the susceptibility to DDT and the duration of the larval period made it desirable to determine the susceptibility to DDT of flies from larvae which pupated first as compared to flies from larvae which pupated last in a given larval population. Because strain "A" was found too resistant to DDT for such a test, strain "W" was selected. Pupae were collected in the same manner as in the experiment to determine the length of the larval period. Susceptibility to DDT was determined in the same manner as the original measurement of resistance. Flies from larvae pupating during the first 48 hours and the last 48 hours of a larval population were tested. Due to the limited number of larvae pupating during these periods and the number of flies emerging within a 24 hour period, only two replicates varying from 79 to 201 flies each were used for each of the five concentrations of DDT used during each 48 hour period. The results are presented in table 2. Although the sample sizes were somewhat variable and limited in number, it would appear that flies from larvae pupating first are considerably more susceptible to DDT than flies from larvae pupating the last 48 hours from a given larval population within a strain. A similar trend was observed within DDT-resistant strains "H" and "O" on a more limited number of flies. This difference of resistance within a strain between larvae pupating first and last further substantiates the close relationship found between the length of the larval stage and the level of DDT resistance of the house fly strains studied.

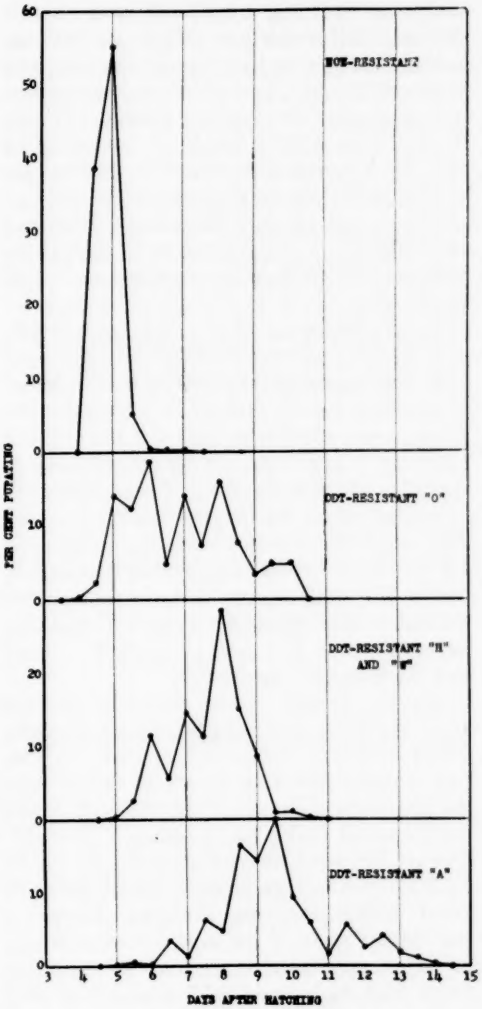

FIG. 1. The length of the larval period of several strains of house flies.

PUPAL STAGE.—The average weights of the pupae of the non-resistant strain and of the highly resistant strain "A", were determined as well as the average weight of the pupae during the first half of the pupation period and the average weight of pupae during the last half of the pupation for each strain. As the larvae pupated, the first 100 and the last 100 pupae were collected from each strain and were weighed individually on a torsion balance 24 hours after pupation. The weights of the non-resistant strain averaged 20.9 mg. with a range of 14.1 to 28.0 mg. The weights of the DDT-resistant strain "A" pupae averaged 20.7 mg. with a range of 13.8 to 29.8 mg. The first 100 pupae from the non-resistant strain had an average weight of 22.0 mg. with a range of 14.8 to 28.0 mg. while the last 100 pupae had an average weight of 19.8 mg. with a range of 14.1 to 27.8 mg. The first 100 pupae pupating of strain "A" had an average weight of 21.7 mg. with a range of 14.8 to 28.2 mg. as compared to the last 100 pupae which had an average weight of 19.7 mg. with a range of 13.8 to 29.8 mg. None of the differences obtained were significantly different either between strains or within a strain.

After the pupae of both the non-resistant strain and the DDT-resistant strain "A" had been weighed they were placed in petri dishes on dampened filter paper. Emergence of both strains reached a peak after 4.5 days. The adults began emerging after the fourth day and none emerged after 5.5 days. Successful emergence was 92 per cent for the non-resistant strain and 89 per cent for the DDT-resistant strain "A". The differences between the two strains in the peak of emergence and the percentage of successful emergence were not statistically significant.

ADULT STAGE.—One thousand adults from both the non-resistant strain and the DDT-resistant strain "A" were sexed. The sex ratio of the non-resistant strain was 56 males to 44 females; the ratio of strain "A" was 46 males to 54 females. The difference between the two strains appears to be statistically significant at the 1 per cent level. Subsequent observations, however, on the sex ratio of the non-resistant strain in later generations showed a variation from 46.5 males and 53.5 females to 50.3 males and 49.7 females. If it is assumed that such a variation would also exist in strain "A", considerable doubt is cast on the difference found between the two strains as being a real difference. Therefore, it is believed, until more adequate proof is obtained, that there is no difference in the sex ratio of the two strains.

Table 2.—A comparison between the susceptibility to DDT of flies from larvae which pupated first and flies from larvae which pupated last in a given larval population.

PER CENT CONC.	PER CENT KNOCKDOWN IN 12 HOURS			
	First 48 Hours		Last 48 Hours	
	Male	Female	Male	Female
0.15	28	7	17	0
0.5	54	24	30	7
1.0	64	32	25	4
2.0	84	42	37	6
4.0	88	54	36	11
Average	64	32	29	6

The non-resistant flies lived an average of 20 days with a range of 2 to 33 days Strain "A" flies lived an average of 22 days with a range of 2 to 36 days. The differences between the length of life of the adults of the non-resistant strain and the DDT-resistant strain "A" were not statistically significant.

To study the pre-oviposition period and the number of eggs laid, a male and female were placed in a screen cage 5 inches high and 2.5 inches in diameter. Twenty cages were used for the non-resistant strain and the DDT-resistant strain "A." Each pair was fed from a glass vial, 7 mm. in diameter by 30 mm. high, which contained diluted milk. A salve tin, 7 mm. by 30 mm. filled with fermented larval medium was placed in each cage as an oviposition site.

The preoviposition period was 3 days for each strain. The average number of eggs laid by females of the non-resistant strain was 504 with a range of 63 to 984, while the average number of eggs laid by females of the DDT-resistant strain "A" was 540, with a range of 110 to 734. The difference in the number of eggs laid by the females of the two strains was not statistically significant.

DISCUSSION.—The laboratory studies of the life history of DDT-resistant strains of house flies show the length of the larval period to be longer in the DDT-resistant strains than in a non-resistant strain thus causing the length of time required for the completion of the life cycle to be in-

creased. This substantiates earlier observations on other DDT-resistant strains made in connection with an earlier study. The lengthened larval period seems to be one of the measured effects caused by the resistance to DDT since it was closely associated with the level of resistance to DDT in the strains studied. Further evidence of this close relationship is offered by the results which indicated flies from larvae pupating the first 48 hours to be less resistant to DDT than flies from larvae which pupated the last 48 hours in a given larval population in a DDT-resistant strain. This is supported further by similar observations made on two other DDT-resistant strains on smaller numbers of flies. These were the only differences found in the study of the life history of the various strains.

The results presented are contradictory to those obtained by Barber *et al.* (1948) who found the pupae of resistant strains to be larger than those of a non-resistant strain. They are also contradictory to those reported by March & Metcalf (1950) showing no significant differences in the life history between a DDT-resistant strain and a non-resistant strain. These differences may represent a variation in the resistant strains studied. In New York State the type of DDT-resistant strains which shows this lengthened life cycle is the only one thus far noted.

If the lengthened larval stage is the result of DDT resistance and applies to all DDT-resistant strains, it means fewer generations of flies will occur in a given period as the level of DDT resistance is increased. The difference in susceptibility to DDT of the flies from early and late pupating larvae may possibly explain in the laboratory, the difficulties in duplicating results with DDT unless one is careful to obtain representative samples of flies from larvae pupating first through to last in a larval population, or to take them consistently at a given period from the time pupation starts. In developing highly resistant strains to DDT, it would seem that more rapid progress might be obtained by selecting flies emerging last from a given larval population in addition to selecting a very small percentage of the adults surviving exposure to DDT after some resistance has been obtained.

SUMMARY.—Laboratory studies of the life history of the house fly, *Musca domestica* L. were conducted to determine the effects of varying levels of DDT resistance. A laboratory strain of flies having no abnormal resistance to DDT was compared to a highly resistant DDT strain, collected in the field, and selected and maintained in the laboratory. Three other DDT-resistant strains with varying levels of resistance to DDT were collected from three different sections of New York State.

The larval periods of the four DDT-resistant strains were found to be significantly longer than the larval period of the nonresistant strain. The length of the larval period seemed to be closely related to the susceptibility of the various strains to DDT. DDT-resistant flies from larvae which pupated the first 48 hours were less resistant to DDT than flies from larvae which pupated the last 48 hour in a given larval population for the strains studied. No significant differences between a highly DDT resistant strain and a non-resistant strain were found in the number of eggs laid, length of egg stage, per cent hatching, length of pupal stage, pupal weights, sex ratio, pre-oviposition period, or length of adult stage.

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The Stable Fly and Its Effect on Seashore Recreational Areas in New Jersey

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For many years the stable fly, or dog fly *Stomoxys calcitrans*, has been an important pest in the resort areas along the New Jersey coast.

Studies of the stable fly were begun in New Jersey in July and August 1946 by Mr. John N. Belkin and were continued in the following year by the author. These studies were instituted at the request of several resort communities, and through their efforts funds were made available by the state legislature for the study of this and other blood-sucking flies.

A similar problem in Florida has been studied and findings have been reported in several papers. Simmons & Dove (1941) reported that the serious outbreaks of dog fly in northwestern Florida originated from fermenting tidal deposits of two bay grasses where flies were breeding in tremendous numbers. Late in the season fermenting peanut leaves and stems left after harvest were also important breeding places of the pest in some areas. In three later papers the above authors (1941 and 1942, a and b) reported on the breeding places of the flies in the bay grasses deposited along inner bays and sounds and the factors to be considered in control activities. A single thorough treatment of the grasses with creosote in diesel oil killed eggs, larvae and pupae and prevented further breeding. In the third paper the authors reported that creosote-water emulsion was just as successful and also more economical since the emulsion eliminated cost of diesel oil, reduced transportation costs and speeded up spray operations.

Simmons (1944) reported on extensive life history studies. Of particular interest was his finding that grass exposed to flies when green, produced the largest number of flies.

An important advance in control methods (Blakeslee 1945) was the introduction of DDT applied as a spray. Emulsions of technical DDT and DDT residual oil both gave effective control when applied to infested weed. A concentration of 0.5 per cent DDT and 2.5 per cent residual oil applied at 2 gallons per 100 sq. ft. gave 90 to 95 per cent mortality of emerging adults, and prevented further extensive breeding.

In New Jersey the stable fly is known locally as the beach fly, since it is on the beaches that the most annoyance is experienced. Actually the fly is a rather sporadic pest in the affected areas and many fewer flies are found than in the Florida outbreaks.

The largest outbreaks of stable fly in New Jersey are found on the sand spit from Point Pleasant southward to Harvey Cedars, a distance of about 25 miles. This area is one of the main resort areas of the state and the stable fly has often caused severe economic losses. The persistent and viscous biting habits, together with their speed, make these flies most annoying. The presence of a few hundred flies is sufficient to cause bathers to leave the beaches and often to cut short their stay at the resort.

Biological and survey studies were centered in Island Beach, an area of sand spit between the Atlantic Ocean on the east and Barnegat Bay on the west, extending south from Seaside Park for about 8 miles. Here are large areas of native dunes and vegetation where biological studies could be made unmolested. Control studies were centered in Seaside Park, since this was representative of the resort communities faced with the *Stomoxys* problem and the town officials were interested in the program to the extent that they aided financially in control studies.

ADULT SURVEY.—Adult flies in these resort areas were known to appear on beaches sporadically. An adult survey was started in 1947. A simple trap consisting of a shingle or metal sheet one foot on a side, painted black and covered with the sticky material known as "*Deadline*" was used. These "deadline" traps were fastened in a vertical position on stakes so that the trap was about two feet above the ground. In 1947 only a few traps were tried but they worked so well that many

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EASTERN BRANCH PROGRAM, 1950.

more were set out in the following three years. At Island Beach these traps were placed in three types of environment, *i.e.*, on the ocean beach near the sand dunes, along the road down the center of the sand spit, and on the bay shore.

All three years (Table 1) the majority of the flies were captured on the ocean beach, in fact, nearly 80 per cent of the flies were taken there. Detailed examination of the trap records shows, however, that flies are taken on the beaches on only a few "fly days," but they are taken rather uniformly throughout the season along the road and bay shore. Personal observations show that these "fly days" are always the result of winds from the west. Repeatedly it has been noted that flies will appear in numbers on the beach within 15 minutes after a west wind starts and they will disappear just as rapidly with a change in wind direction. Occasionally, flies will invade beaches when the wind is southwest or northwest, but practically never with the wind from another quarter.

The seriousness of annoyance depends on abundance of flies as determined by breeding conditions. The worst fly infestation encountered was at Island Beach on September 3 and 4, 1947. Similar conditions were reported by various persons on beaches northward to Point Pleasant. Four traps were then in operation at Island Beach on the ocean beach. Numbers of flies captured on these traps are recorded in table 2.

It is apparent that flies reached a peak the evening of September 3, though they were numerous at all times. Most of the time driftwood on the beach was covered with flies and there were two or three flies on every blade of grass. Life on the beach was unbearable. Wind was steadily from the west for the 2 day period.

During this outbreak it was determined that only about 10 per cent of flies coming to traps were caught.

Other observations showed that *Stomoxys* are attracted especially to dark colors and attack most readily those persons who are dressed in dark clothes. When two persons counted flies on their trouser legs at one minute intervals for 10 minutes, they found that 20 times as many flies rested on dark blue as on light blue trousers. With this infestation, as at other times, flies were found to move normally within two or three feet of the ground and therefore attack from the knees down any one walking on the beach.

In using traps on the ocean beach, it was found that largest numbers of flies were always caught by traps facing west and seemed to move with the wind. In other habitats the catch was more nearly even between traps facing east and west.

The source of this outbreak of flies was found to be the vegetation on the bay shore. It was possible to find thousands of pupal shells in the decaying vegetation high on the beach where they had been washed from the weed. The outbreak followed by about 10 days a period of

Table 1.—Average catch of *Stomoxys* on traps in three environments at Island Beach.

	Average No. Flies per Trap During the Season		
	On Ocean Beach	Along Road	On Bay Shore
1948	338.4	91.0	50.4
1949	119.1	12.6	12.4
1950	286.2	5.2	74.1

Table 2.—*Stomoxys* on deadline traps on Ocean Beach, September 3 to 6, 1947.

	Trap			
	4	5	6	7
Sept. 3				
10:00 A.M.	65	X	12	5
11:00	71	9	37	7
12:00	55	12	11	2
1:00 P.M.	31	6	8	21
2:00	47	3	10	4
3:00	26	12	6	4
4:00	83	50	22	17
5:00	85	41	5	15
6:00	156	41	12	11
7:15	622	141	86	35
Sept. 4				
9:00 A.M.	X	424	364	66
10:00	X	X	71	26
11:00	70	66	42	47
12:00	17	19	11	17
1:00 P.M.	7	17	11	30
2:00	13	35	28	46
3:00	21	40	43	64
Sept. 6				
10:00 A.M.	83	61	40	26
Total	1452	977	819	443
Per Cent	39.3	26.5	22.2	12.0

X—No observation.

high tides which had stranded large amounts of seaweed high on the beach and excellent breeding conditions resulted.

BREEDING HABITS OF STABLE FLY.—At the outset of our studies it appeared that the marine grasses deposited on the bay shore are the source of *Stomoxys* breeding. Usually larvae are very difficult to find in suspected breeding areas because they avoid being exposed to light and are capable of rapid movement, and when disturbed they quickly crawl out of sight between closely appressed blades of grass. Caging piles of vegetation and counting adult flies which emerged was found to be the best method for getting information on breeding places. Cages were constructed of screen wire on all sides and with an exit hole in one corner leading into a jar. Adults were collected by covering the cage with a dark cloth except for a small area around the jar. Flies were easily counted as they came to the light area and entered the jar.

On July 23, 1948, infested vegetation was found at Seaside Park and was estimated to contain 50 to 100 larvae and pupae per bushel. Lots of 1.5 bushels of seaweed were placed in four cages and observed for 6 weeks. Emergence of adults from these cages is set forth in table 3.

Table 3.—Emergence of *Stomoxys* adults from caged lots of decaying vegetation.

	No. Flies Emerging			
	Cage 1	Cage 2	Cage 3	Cage 4
July				
26	0	0	24	34
29	0	0	37	82
30	22	23	41	66
31	17	29	11	81
Aug.				
2	115	96	185	137
3	43	24	72	15
5	46	81	44	55
6	12	24	22	25
9	9	6	10	32
10	13	7	46	43
11	29	7	40	36
13	39	3	20	16
14	12	8	45	14
17	17	9	62	44
18	6	8	48	5
19	6	4	37	3
21	0	0	24	2
22	0	2	7	0
23	3	0	7	2
24	2	1	11	1
25	0	0	4	0
26	0	0	5	0
27	0	0	0	0
to Sept. 14	0	2	2	0
Total	391	333	803	693

Flies continued to emerge from this material for a month and two flies emerged 6 weeks after the weed was caged. The greatest number of flies emerged about 2 weeks after caging. From these data it will be seen that an average of 555 flies per cage or 370 per bushel of weed emerged several times the number expected. Some idea of the numbers of flies can be realized by pointing out that an estimated 100 bushels of weed were piled in this one location and there were several locations like it in Seaside Park. Nor were the maximum number of flies reared from this vegetation. Uncaged material could and does support successive generations.

The above data also show that the life cycle under New Jersey conditions is longer than that reported by Simmons (1944) in Florida. These and other observations have shown that the minimum period for development from egg to adult is two weeks, but usually three to four weeks are necessary.

Stomoxys larvae were found to breed at lower temperatures than those preferred by other muscoid larvae. Temperatures of the decaying weed taken in a number of locations in both large and small deposits of grass ranged from 62° to 134° F., but *Stomoxys* larvae were not found at temperatures above 88° F. Heaviest breeding was found when temperatures were between 68° and 78° F.

A great many observations failed to reveal any sure method of telling whether flies would breed in vegetation. It was apparent, however, that seaweed need be out of water only a day or two for flies to be attracted to it and after the weed is out of water for two or three weeks flies oviposit much less readily. Thus very heavy broods often follow very high tides by two to four weeks.

CONTROL OF *Stomoxys*.—Control studies with insecticides which kill adults as they emerge, were started as soon as the heavy breeding areas described above were located. This approach had been used successfully by Blakeslee (1945) in Florida where he obtained 90 to 95 per cent control by applying 0.5 per cent DDT at the rate of 2 gallons per 100 sq. ft. of surface.

For preliminary tests, cages 4 feet long,

15 inches high, and 3 feet wide were constructed. The frames were covered on all sides and the top with blue denim cloth except for a strip 4 inches wide down the length of the top. Over this opening a fly trap was placed and emerging adults were captured. The number of flies captured served as an index of the effectiveness of the chemical applied to the seaweed.

Piles of weed four feet long, 2.5 feet wide, and 1 foot high were sprayed with 1 quart each of 0.5 per cent emulsions of DDT, methoxychlor, and TDE in these cage tests. Sprays were applied on August 6 with a 3 gallon compressed air cylindrical sprayer. As soon as they were sprayed, piles of weed were covered with the cages. Results are set forth in table 4.

Assuming that comparable numbers of larvae and pupae inhabited the weed in each cage, the control was 89 per cent or better with all three insecticides.

Other lots of vegetation of large size were similarly sprayed with 0.5 per cent DDT emulsion and covered with larger cages, the largest cage having dimensions of 6 by 8 by 3 feet. Only 14 flies emerged in the largest cage. In all of these tests, estimated kills were 90 to 95 per cent.

The success of these tests led to a community-wide control program in 1949 and 1950 in Seaside Park Borough. The plan both years called for spraying every two weeks of all deposits of vegetation piled along the bay shore or removed to other locations in town. In 1949 the object was to find out whether 0.5 per cent emulsions of DDT or methoxychlor applied to decaying vegetation at 2 quarts to 100 sq. ft. of surface would be successful in reducing fly annoyance on the ocean beaches. To determine this, sprays were applied from a 25 gal. power sprayer operated at 150 pounds pressure and using 50 to 150 feet of hose and an orchard type nozzle. The sprayer was operated along the road which parallels the bay and the necessary length of hose was used to reach the deposits of vegetation.

In 1950 a further object of the program was to test various equipment to find a more satisfactory type than the 25 gallon sprayer used the previous year. DDT and methoxychlor remaining from the 1949 program were used and then DDT was used the rest of the season in the same fashion as the previous year, *i.e.*, 0.5 per cent applied 2 quarts per 100 sq. ft. of surface. Throughout most of the season a 200 gallon sprayer mounted on a truck was used with up to 150 feet of hose. A single-nozzle orchard gun, a trigger shut-off outfit and a three nozzle broom were compared in these studies.

The amount of spray applied and dates of application for both years are given in table 5.

The effectiveness of the control program was measured by the use of traps and by personal observations. In 1949 in addition to the traps a man was stationed at Island Beach and made daily observations on fly abundance. Whenever flies were abundant at Island Beach he immediately visited Seaside Park for comparison and evaluation of the control program. In 1950 observations at Seaside Park were made daily by the lifeguard captain, who visited all beaches at frequent intervals. At Island Beach visual observations were made by the writer and traps were checked at least once a week.

The control program reduced fly annoyance an estimated 90 to 95 per cent both seasons. In 1949, traps captured 12 flies in Seaside Park as compared with 174 on traps along the bay shore in Island Beach. In 1950, 5 flies were captured at Seaside Park in comparison with 741 at Island

Table 4.—Emergence of *Stomoxys* from decaying vegetation treated with insecticides.

TREATMENT	FLIES EMERGING	PER CENT CONTROL
0.5% DDT	29	92.4
0.5% methoxychlor	41	89.3
0.5% TDE	29	92.4
0.5% DDT	22	94.2
Untreated	382	

Table 5.—Application of spray to seaweed deposits at Seaside Park in 1949 and 1950.

DATES	0.5% DDT EMULSION	0.5% METHOXYCHLOR EMULSION
June 27, 29, 1949	150 gals.	25 gals.
July 14	175	100
July 28	175	75
August 12	250	75
August 29 and 30	200	50
July 5, 1950	100 gals.	25 gals.
July 18		150
August 2	250	
August 17	350	
September 1	300	

Beach. As most of the flies at Seaside Park were taken early in the season, evidently breeding was practically eliminated in Seaside Park late in the season.

Personal observations both years similarly show that excellent control was obtained. Early in both seasons, before the second spray was applied, fly annoyance was encountered on 1 or 2 days at Seaside Park. In 1949 there was annoyance on the beaches on August 9 and in 1950 on July 18 and 27. On all of these dates as well as on a number of others there was fly annoyance at Island Beach. When annoyance was encountered at Seaside Park after the control program was well under way there was a southwest wind and it is assumed that the major portion of the flies moved into Seaside Park from Island Beach. It should be mentioned too that on every occasion when flies were bad at Seaside Park they were worse at Island Beach and other nearby communities.This had not been true in years before the control program was instituted.

No differences in fly control were noted in 1949 between DDT and methoxychlor and, therefore, DDT was used through most of 1950. It is cheaper and easier to procure in emulsion form.

Tests of equipment in 1950 showed that a truck-mounted sprayer with a 200 gallon tank and a 3-nozzle broom made possible the speediest and easiest application of spray. The operation can be done with a two man crew, but a three man crew could do the job almost twice as fast.

Costs of these operations were low. With the equipment used in 1950 it was possible to do the job in 2 to 3 hours with a three man crew or at a cost for labor of 6 to 9 dollars per application. Spray materials for the six applications cost about $60.00. It is evident that it would be economical for a community to purchase the necessary equipment for a *Stomoxys* control program. Equipment could also be used in other insect control, and labor could be borrowed from other duties for half a day once in 2 weeks to make the necessary applications of spray.

DISCUSSION.—In New Jersey the *Stomoxys* problem in seashore recreational areas is likely to increase. In fact, the annoyance from stable fly has increased materially in the last 5 years. This increase has been due to the increase in aquatic vegetation which washes ashore in Barnegat Bay.

Some 15 to 20 years ago eel grass was more abundant but was wiped out within a year or two by a disease. Conservation interests have been working ever since to reestablish the grass as duck food. The grass is now again well established and each year is moving farther south in Barnegat Bay. It is evident that conservation interests would vigorously oppose measures to eliminate growth of these marine plants. They will probably continue to increase and the *Stomoxys* problem will probably increase in the same proportion.

The control program now worked out can handle *Stomoxys* outbreaks without great expense. Removing and burying infested weed will also control the flies. Frequently the deposits along the bay are used as a base on gravel roads, and with such use, removal from the beach becomes economically feasible and cheaper than chemical control.

At various times local authorities have tried to handle the vegetation by dragging it into the bay, but it soon washes back. If high tides do not deposit the drift on shore it is often necessary to remove it from the water by hand. If left in the water, decomposition is rapid and disagreeable odors result. Sulfur compounds from the process discolor painted surfaces in the vicinity. Such removal and piling of the weed increases the stable fly problem and the necessity for chemical control.

It is difficult to measure the economic benefits from such a program. However, the cost of the program in taxes would be equalled by profits to business in the community if, because of freedom from *Stomoxys* bites, vacationists remained on beaches only one additional day in midsummer.

SUMMARY.—Studies of biology and control of *Stomoxys calcitrans* along the New Jersey seashore were started in 1946. A survey of flies in three environments was made for 3 years using shingles coated with a sticky material. Fly annoyance on the ocean beach was found to be sporadic and always associated with westerly winds. Flies appeared on beaches within 15 minutes after wind shifted west and disappeared just as readily with unfavorable wind. The life history was found to be somewhat longer than in areas farther

south. Breeding took place in deposits of marine vegetation above high tide line on the bay shore. *Stomoxys* breeding was found at temperatures to 88° F. Other muscoid larvae were found at higher temperatures.

Successful fly control of adult flies with tests of 0.5 per cent emulsions of DDT, methoxychlor and TDE when sprayed on the surface of weed to prevent emergence of adults led to community-wide control at Seaside Park. Over a 2-year period an estimated 90 to 95 per cent control of emerging flies was obtained with the DDT and methoxychlor applied at 2 quarts per 100 sq. ft. of weed surface. Methods of application and types of equipment used are discussed. Other possible control techniques and the nature of the problem are discussed in some detail.

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Inversion of Cane Sugar in the Honey Stomach of the Bee

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The honey bee, *Apis mellifera* L., is well known for its ability to gather nectar from flowers in the field and to transform it into honey. The process of converting nectar into honey is both chemical and physical in nature, the chemical process consisting of the hydrolysis of cane sugar (sucrose) into invert sugar (glucose and fructose), and the physical process consisting of evaporatiion of the solution to a thick sirup.

Determinations of the chemical composition of honey are relatively easy because samples for analysis are readily obtained. On the other hand, the composition of nectars from various honey plants is not well known because of the difficulty of acquiring a sufficient volume of the nectar. Park (1929) showed that the Abbé refractometer could be used to determine the total-sugar content of nectar. Since then nectar studies have been conducted by catching honey bees on the flowers, placing the contents of their honey stomachs on the prism of the refractometer, and determining the total solids in the nectar. A few investigators—for example, Bonneir (1878), Beutler (1929), and Vansell (1944)—have used a capillary pipette to obtain sufficient nectar from some flowers for laboratory analysis.

The experiments reported herein were undertaken from February 7 to April 5, 1950, at Baton Rouge La., to determine (1) the rapidity of hydrolysis, or inversion, of cane sugar (sucrose) in the honey stomach of the bee, (2) the value of the refractometric method compared with the chemical method for the analysis of nectar or cane-sugar sirups collected from the honey stomach, and (3) the effect of internal secretions on the concentration of the nectar or cane-sugar sirups in the honey stomach. This paper reports results obtained when sugar sirups were fed to caged honey bees; a later paper will report results of tests with bees working on various flowers.

METHOD.—Experimental sirups were made to approximate concentrations of 25, 50, and 75 grams per 100 ml. of solution.

[1] In cooperation with Louisiana State University.

The exact concentrations were determined by analysis and have been reported in tables as zero time values.

Worker honey bees were picked from the inner cover of the hive and placed in screened cages. These cages were 3 by 3 by 1.5 inches, inside measurement, with screened sides and with openings in the top to receive the feeder vials. Each cage contained 30 to 50 bees, fed from two inverted vials, the caps of which contained four small feeding holes. Each sample of bees was caged between 8 and 8:15 A.M. and placed in a constant-temperature cabinet at 93° F. for nearly 1.5 hours, so that the bees could use up all or nearly all the honey that might have been present in the honey stomach. (Honey bees use up their body stores rapidly when they are active and are not allowed access to food. It is not unusual for bees to starve to death within 2 hours after being caged, when kept at 93° F. without food.)

The bees were then removed to the laboratory, which was maintained at 77° to 79° F., for the remainder of the experiment. The glass feeder vials containing the experimental sugar sirups were placed on the cages at approximately 10 A.M., and left there for 30 minutes to 1 hour. After the feeders were removed, the bees had access to no food other than that in their honey stomachs. At stated intervals bees were taken from the the cages, the honey stomachs removed, and the contents emptied into small glass vials. This operation required 10 to 15 minutes per sample.

The contents of a minimum of 10 honey stomachs were required for the chemical determination of invert sugar. The collected stomach contents were well mixed, and two 0.10-ml. portions were pipetted into 100-ml. volumetric flasks. The flasks were made up to volume with distilled water, the contents well mixed, and an aliquot was removed from each for the determination of invert sugar by the method of Shaffer & Hartman (1921). A second set of aliquots was hydrolyzed by the Association of Official Agricultural Chemists method (1940), and invert sugar determined again. The difference between the determinations of the hydrolyzed and unhydrolyzed sugars, with correction for molecular weights, is the sucrose content.

As the work progressed, the data showed what appeared to be anomalous results. Although errors were introduced through dilution techniques and drainage in pipetting sirup solutions, it is thought that sampling was the main source of error. The sources of sampling error, which can be reduced to a minimum but not entirely eliminated are as follows: (1) variation in age of bees as they are collected from the hive; (2) extent of depletion of contents of honey stomachs prior to feeding; and (3) differences in time elapsed between feeding and removal of honey stomachs of individual bees at any particular sampling, since all bees within a cage or among cages did not begin feeding at the same time.

In the latter part of the work 20 bees (five bees from each of four cages) were taken as a sample (table 2 and experiment 2 in table 3) instead of 10 bees from 1 cage as was done in the early part of the work. In all experiments the honey stomachs of several bees were examined visually for evidence of depletion just prior to feeding. It is possible that very small quantities of honey might have been present at feeding time, although depletion was so complete that several bees in each cage were either dead or too weak to reach the feeder vials and recover.

EXPERIMENTS.—In preliminary experiments conducted to determine changes in sugar sirups fed to worker bees, Oertel (unpublished data) fed caged bees sirups containing 20 to 68 per cent of cane sugar. Refractometric analysis of recovered sirup from the stomachs at different intervals showed that generally the recovered sirups contained less total sugar than the original sirup. This analysis suggested that the bees had either diluted the solution in some manner or selectively removed part of the sugar. In tests conducted with tied-off stomachs, the walls of the honey stomachs were found to be impermeable to the passage of sugar molecules.

A series of experiments were undertaken to investigate in greater detail the change in concentration of sugar sirups recovered from honey stomachs of bees. The techniques described under Methods were used. Table 1 shows data for bees fed sirups containing approximately 25, 50, and 75 grams of sucrose per 100 ml. After 2.5 hours in the bees' stomachs the sirups originally containing nearly 25 and

50 grams of sucrose had sucrose concentrations within the range of that of natural honey, although the concentration of total sugars was much lower. It can be concluded, then, that the honey bee secretes a very active invertase, which rapidly brings about the conversion of sucrose to invert sugar (glucose and fructose).

Moreover, in the three experiments reported in table 1 the total-sugar concentration decreased with length of time in the honey stomach. Since neither water nor sugars can diffuse through the walls of the honey stomach, it is concluded that the bee secretes fluid into the honey stomach. The last column of table 1 gives the calculated change in concentration, or dilution, on the basis of no diffusion of sugars or water through the walls of the honey stomach. In spite of this dilution, the volume of solution in the honey stomach slowly decreases with time because of its passage into the ventriculus of the bee.

Further evidence that internal secretions of the bee cause dilution of the honey stomach contents may be seen from the data in table 2. Caged bees were fed a solution containing 50 grams of invert sugar (25 grams each of glucose and fructose) made up to 100 ml. in volume. Again one may note a gradual decrease in sugar concentration. As further evidence that the bee is secreting material, a qualitative test for protein (trichloroacetate precipitation) gave positive results after the sugar solution had remained in the honey stomach for 2.5 hours.

The experiment in which sucrose solutions (approximately 50 g. per 100 ml.) were used was repeated 2 weeks later, with bees from the same hive. Large differences were indicated for amount of inversion and dilution, as shown in table 3. No explanation can be given for these differences. Smaller, though significant differences were shown in three additional experiments in which sirups containing 75 grams of sucrose in 100 ml. were used, the dilution ranging from 25.0 to 40.6 per cent 4.5 hours after feeding.

Apparently an unknown factor or factors influence the degree of dilution and consequently the rate of hydrolysis. From the data present in tables 1, 2 and 3 and other unpublished data, it appears that there is an immediate secretion of invertase, which results in both dilution and hydrolysis, followed by little or no secretion for 1 to 2 hours.

After this period of inactivity there is an increased secretion, resulting in greater dilution and hydrolysis. (Note table 1, the 25-gram strength at 0.5, 1, and 1.5 hours, and the 75-gram strength at 1.5 and 2 hours; table 2 at 1.5 and 2.5 and table 3, experiment 2, at 1, 1.5 and 2.5 hours.)

Table 1.—Inversion and dilution of sucrose in the honey stomachs of honey bees.

Approximate Sucrose Concentration of Sirup (Grams per 100 Ml.)	Hours from Start of Feeding	Number of Bees per Sample	Analysis of Stomach Contents (Grams per 100 Ml.)			Per Cent Inversion	Per Cent Dilution
			Total Sugar	Invert Sugar	Sucrose		
25	0	—	24.7	0.5	24.2	—	—
	0.5	10	21.5	5.3	16.2	23.6	14.9
	1	10	22.0	4.8	17.2	21.0	12.3
	1.5	12	21.6	10.2	11.4	45.9	14.4
	2.5	15	18.8	10.7	8.1	55.7	31.4
50	0	—	46.3	0	46.3	—	—
	0.5	10	46.3	11.6	34.7	24.1	0
	1	10	43.3	18.2	25.1	40.8	6.9
	1.5	10	37.2	17.3	19.9	45.3	24.5
	2.5	16	29.2	24.0	5.2	81.4	58.6
75	0	—	73.9	0	73.9	—	—
	1	10	62.8	21.1	41.7	32.5	17.7
	1.5	10	60.8	25.3	35.5	40.4	21.5
	2	10	60.3	23.2	37.1	37.2	22.6
	3	10	58.5	33.9	24.6	56.7	26.3
	4	14	52.6	28.7	23.9	53.2	40.5
	5	19	53.3	38.4	14.9	71.0	38.6

Table 2.—Dilution of invert-sugar solution in honey stomachs of honey bees fed a sirup containing 50 grams per 100 ml.

Hours from Start of Feeding	Number of Bees	Grams of Invert Sugar	Per Cent Dilution
0	—	49.0	—
0.5	20	45.6	7.5
1	19	44.7	9.6
1.5	19	42.0	16.7
2.5	16	42.3	15.8
3.5	14	38.9	26.0

An experiment was conducted in which chemical determinations were made on honey stomach contents of bees that had been fed for 0.5 hour on a sugar solution. The contents of 60 stomachs were removed after feeding and stored in a vial (*in vitro*) at 77 to 79°F., to compare the rate of inversion *in vivo* with that *in vitro*. As shown in table 4 the amount of inversion at the end of 24 hours *in vitro* was equal to that obtained after 3 hours *in vivo*. Bosch *et al.* (1932), feeding a 50 per cent sucrose solution, showed an inversion of 51 per cent after storage in the hive for 22 hours. This figure checks well with the 56 per cent inversion in 24 hours reported here. The higher rate of inversion in the bee is probably caused by the continued addition of invertase to the honey stomach contents. The house bees may add invertase each time they transfer nectar from one location to another in the hive. This would account for the almost complete hydrolysis of sucrose in honey and for the fact that nectar is converted to honey in 3 or 4 days.

In the *in vitro* experiment (Table 4) the concentration of total sugar collected from the honey stomachs was higher than in the original solution (67.0 per cent). A half hour was required to collect the sample from 60 bees. Each honey stomach, while being held at the top of a glass vial 44 mm. tall, was punctured to allow the contents to flow down the tube. During the operation enough evaporation took place to concentrate the sirup from its original value of 67.0 grams to an average of 71.1 grams of total sugar per 100 ml.

The refractometer has been recommended and used for determination of total solids in nectars and honey stomach contents. It gives valid data for total solids only when pure solutions are used. The data presented above clearly demonstrate that the honey stomach contents of bees fed cane-sugar sirup contain a mixture of sucrose, glucose, and fructose. A further objection to the refractometric method is that it gives no information on the amounts of invert sugar and sucrose present, so that in a study of the changes occurring in the honey stomach the data obtained by its use are of little value (Table 5). Another objection is that the internal secretions contain dissolved non-sugar substances—protein, for instance—that will affect the refractive-index reading.

DISCUSSION.—Rapid inversion and dilution of the honey stomach contents are

Table 3.—Inversion and dilution of sucrose in the honey stomachs of honey bees fed sirups containing approximately 50 grams of sucrose per 100 ml. on two dates 2 weeks apart.

Hours from Start of Feeding	Number of Bees per Sample	Analysis of Stomach Contents Grams per 100 Ml.			Per Cent Inversion	Per Cent Dilution
		Total Sugar	Invert Sugar	Sucrose		
		Experiment 1, March 14, 1950				
0	—	46.3	0	46.3	—	—
0.5	10	46.3	11.6	34.7	24.1	0
1	10	43.3	18.2	25.1	40.8	6.9
1.5	10	37.2	17.3	19.9	45.3	24.5
2.5	16	29.2	24.0	5.2	81.4	58.6
		Experiment 2, March 29, 1950				
0	—	49.5	0	49.5	—	—
0.5	19	47.0	6.1	40.9	12.4	5.3
1	19	43.4	9.8	33.6	21.7	14.1
1.5	17	44.7	10.4	34.3	22.4	10.7
2.5	19	43.7	9.2	34.5	20.2	13.3
3.5	18	40.9	16.3	24.6	38.6	22.6

Table 4.—Rate of inversion of cane-sugar sirup *in vivo* and *in vitro* in the honey stomach of the honey bee.

Hours from Start of Feeding	Number of Bees Per Sample	Analysis of Stomach Contents (Grams per 100 Ml.)			Per Cent Inversion	Per Cent Dilution
		Total Sugar	Invert Sugar	Sucrose		
		Sirups incubated *in vivo*				
0	—	73.9	0	73.9	—	—
1	10	62.8	21.1	41.7	32.5	17.7
1.5	10	60.8	25.3	35.5	40.4	21.5
2	10	60.3	23.2	37.1	37.2	22.6
3	10	58.5	33.9	24.6	56.7	26.3
4	14	52.6	28.7	23.9	53.2	40.5
5	19	53.3	38.4	14.9	71.0	38.6
		Honey-stomach contents removed after ½ hour and incubated *in vitro*				
0	—	67.0	1.2	65.8	—	—
0.5	[1]	70.4	6.3	64.1	8.6	—
1		69.9	12.0	57.9	16.5	—
2		71.5	17.7	53.8	23.0	—
3		71.3	19.8	51.5	26.8	—
4		70.8	21.0	49.8	28.6	—
24		72.4	41.5	30.9	56.0	—

[1] Contents of 60 stomachs divided into 6 equal parts.

evident from the tests reported here. The bee may spend an hour or more going from flower to flower before returning to the hive with the nectar. The rather wide variation found in sugar concentration of nectar taken from several bees, all working on the same flower species, and of the sample being taken within a few minutes as shown by Vansell (1939), Oertel (1944), and others, is probably due in part to the dilution from glandular secretions added to the nectar in the honey stomach. Decreases in sugar concentration were observed by Park (1932) in studies on honey stomach contents, but the changes were reported as being very small. Probably larger changes would have been observed if the analyses had not been made by the refractometer, if the sirup had remained in the honey stomach for more than 30 minutes, and if the sirup had not been mixed with honey possibly present in the honey stomach.

It is generally agreed that the glands of the honey bee go through a series of changes in development. Glandular activity rises to a peak and then declines, according to the age of the bee and its hive duties (Evenius 1937). Inglesent (1940) has clearly shown how the age and hive activity of the honey bee are related to its gland functions.

In addition to the glandular secretions as a source of dilution, transfer of fluid through the honey stomach walls must be considered. According to Snodgrass (1925) and Wigglesworth (1947), the honey stomach is part of the eosophagus (of stomodeal origin) and is lined with a thick folded intima. Therefore it is not likely that fluid passes through this

Table 5.—Comparison of refractometric and chemical methods of determining sucrose in the stomach contents of honey bees fed sirup containing approximately 50 grams of sucrose per 100 ml.

Hours from Start of Feeding	Refractometric Method		Chemical Method (Grams per 100 Ml.)		
	Refractive Index	Per Cent of Sucrose	Total Sugar	Invert Sugar	Sucrose
0	1.4085	45.0	49.5	0	49.5
0.5	1.4035	42.75	47.0	6.1	40.9
1	1.4035	42.75	43.4	9.8	33.6
1.5	1.4010	41.0	44.7	10.4	34.3
2.5	1.4015	41.5	43.7	9.2	34.5
3.5	1.3975	39.5	40.9	16.3	24.6

membrane. Oertel (unpublished data) and Pasedach-Poeverlein (1940) have found that the walls of the honey stomach are impermeable to dissolved sugar molecules and to water molecules.

In the light of the work on glandular activity and apparent lack of permeability of the honey stomach walls, it is concluded that most of the dilution is caused by the addition of glandular secretions to the contents of the honey stomach. Snodgrass (1925) states that the principal function of the honey stomach is the storage of either the nectar that the worker bee carries to the hive or the honey that it transports on certain occasions. Another function, perhaps of equal importance to that postulated by Snodgrass, is the addition of invertase to the nectar in the honey stomach for its conversion to invert sugar, which is the principal sugar of honey.

SUMMARY.—In the spring of 1950 experiments were conducted at Baton Rouge, La., to determine (1) the rapidity of inversion of sucrose in the stomach of the honey bee, (2) the value of the refractometric method compared with a chemical method for the determination of sugars in the honey stomachs, and (3) the effect of internal secretions on the dilution of honey stomach contents. *In vitro* changes in collected honey stomach contents were also investigated.

Both rapid inversion of sucrose and dilution of honey stomach contents were observed. There appeared to be an initial dilution upon the ingestion of sugar sirups, followed by little change for an hour or two, and then a second increase in dilution.

The inversion of sugar sirups was much more rapid *in vivo* than in honey stomach contents *in vitro*.

It has been indicated that the refractometric method cannot be satisfactorily used to study chemical changes of sugar sirups and nectars in the honey stomach.

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HAEUSSLER A NEW DIVISION HEAD

Gilbert J. Haeussler was named as leader of the Division of Truck Crops and Garden Insect Investigations, BEPQ, succeeding William H. White who died March 14, 1951. Mr. Haeussler has been engaged for 16 years in the Bureau in research on the control of insect pests of fruits by means of their natural enemies and has traveled extensively in foreign countries searching for parasites of the oriental fruit moth.

DR. THOMAS E. SNYDER RETIRES

Dr. Snyder, well-known authority on termites and their control, retired June 30, 1951 from the U. S. Department of Agriculture, after 42 years of service. He is the originator or instigator of the most modern methods of termite control. The author of more than 200 scientific and popular articles on termites, Dr. Snyder expects to continue his studies on these insects, from his office in the U. S. National Museum.

The Chemotherapeutic Value of Several Insecticides for Larvae of Certain Leaf Mining Insects[1]

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The chemotherapeutic value of insecticides for leaf mining insects, the larval stages of which have been considered inaccessible to such materials heretofore, is a subject that has received little attention. The fact that insecticides may be absorbed and translocated to various parts of a plant has been established by several investigators. Fulton & Mason (1937) have shown that derris constituents were translocated in bean plants. More recently Questal & Connin (1947) grew corn in soil treated with parathion and found that the leaves and stalks of the plants were lethal to European corn borer larvae. Starnes (1950) reported that aqueous suspensions and benzene extracts of potato foliage and tubers grown in soil containing the gamma isomer of benzene hexachloride were highly toxic to *Aëdes* larvae. Huffaker (1948) has shown that DDT was translocated in bean plants.

In the field of plant pathology Howard & Horsfall (1950), in developing concepts in plant chemotherapy, point out that "antidotal chemicals can be supplied the plant by direct stem injection, foliage application and intake, soil surface coverage or drench, incorporation in the soil by cultivation, and hydraulic soil impregnation in suspension or solution". Since the principle of plant chemotherapy is that of supplying some agency that will assist the plant in overcoming disease, it is postulated that such agencies or chemotherapeutics can be in the nature of antitoxin, antimetabolite or antipenetrant. It would appear from the entomological publications cited above that the principal methods involved have dealt with antimetabolites administered by means of foliage application and intake, and by incorporation in the soil.

The objective of the research reported herein was that of determining the relative chemotherapeutic value of several insecticides when administered by means of foliage application and intake. In order to obtain a reliable index of the chemotherapeutic value of the materials under investigation, three species of leaf mining insects whose larvae develop wholly within the host leaves were selected. The fact that large numbers of all three species were available under field conditions facilitated certain phases of the study. The research was undertaken in 1949 and 1950 and involved the boxwood leaf miner, *Monarthopalpus buxi* (Laboulb.), the holly leaf miner, *Phytomyza ilicis* (Curt.), and the birch leaf miner, *Fenusa pusilla* (Klug.)

Materials.—The complete details relative to the materials and concentrations used in each experiment are given in tables 1 to 4. All, except nicotine sulfate, were chlorinated hydrocarbon insecticides in the form of wettable powders and included 50 per cent DDT, 40 and 50 per cent chlordane, 25 per cent aldrin, 25 per cent dieldrin, 25 per cent lindane and 50 per cent benzene hexachloride (6 per cent gamma isomer and 44 per cent other isomer of hexachlorocylohexane). The nicotine sulfate was employed as the conventional 40 per cent solution. All of the materials, except aldrin and dieldrin, were available commercially. Aldrin and dieldrin were supplied for experimental purposes by the manufacturer. Additional wetting agent was used with all insecticides as indicated in the various experiments. One, a polyoxyethylene sorbitan monolaurate,[2] used in the first experiment was later replaced by another, a phthalic glyceryl alkyd resin.[3] All materials were applied as sprays using a conventional power-operated, hydraulic sprayer and spray gun.

Boxwood Leaf miner.—This insect is one of the most serious pests of boxwood, *Buxus* spp., in Rhode Island where the life history of the insect corresponds to that outlined by Hamilton (1925). During oviposition the female inserts a needle-like, curved ovipositor through the lower surface of the leaf and deposits each egg singly in an enlarged slit in the mesophyll. Shortly after oviposition no opening is visible in the leaf. The first instar larva lies curled up crescent-shaped in a tiny cavity caused during oviposition. After the first molt the larva assumes a spindle shape, and a ring of plant cells surrounding

[1] Contribution No. 771 from the Rhode Island Agricultural Experiment Station, Kingston, R. I.
[2] *Tween 20.*
[3] *Triton B-1956.*
Eastern Branch Program, 1950.

the cavity enlarges to form a gall-like growth. The cavity increases in size as the larva grows. Throughout its development the larva is enclosed by live plant tissue, the upper epidermis and pallisade tissue being above and the spongy tissue and lower epidermis below the disc-shaped cavity.

In 1949 adult emergence began on May 20 and extended over a period of 12 days. Box, 4 to 5 feet tall, the leaves of which were heavily infested with first instar larvae, were used in the experiment. On July 7, 1949, each of the materials listed in table 1 was applied to four replicated plants. At that time it was observed that the aldrin formulation flocculated slightly, while the 50 per cent chlordane formulation formed an almost unsuspendible sludge when added to the water in the spray tank. A second application of materials was made to two of the box in each treatment on August 19 when most of the larvae were in the second instar. At that time, 4 pounds of 25 per cent lindane were substituted for 2 pounds of benzenehexachloride, and 2.5 pounds of 40 per cent chlordane were substituted for 2 pounds of the 50 per cent chlordane formulation. All of the chlorinated hydrocarbon insecticides except aldrin formed desirable suspensions when added to the water in the spray tank. Aldrin formed an extremely flocculant type of suspension. During the period of April 11 to 30, 1950, 125 random leaves from the plants in each treatment were removed, the upper and lower leaf surfaces separated and examined for live and dead larvae. The exoskeletal remains of the dead larvae, even those of the first instar, were remarkably well preserved at the time the data were recorded. While almost all of the live larvae were full-grown, an occasional specimen was discovered that corresponded to the description given by Hamilton (1925) for the second and third instars.

There was a variation in the degree of infestation among the plants in the experimental area. The minimum average number of larvae, both living and dead, found per leaf was 3.1, while the maximum average number was 6.5. In all treatments, except aldrin, the larval survival between replicates was relatively constant, regardless of the degree of infestation.

The data presented in table 1 show that all materials, except chlordane and benzene hexachloride, exerted some influence on the survival of larvae inside of the leaves. Dieldrin and aldrin were the most effective chemotherapeutants. Aldrin was less effective than dieldrin, possibly because of the poor physical properties of the latter material when it was applied. There was no difference in the degree of larval survival in leaves sprayed once or twice with dieldrin or aldrin, but a second application of spray in the nicotine sulfate, DDT, and benzene hexachloride-lindane treatments did result in a significant reduction as compared with the check treatment.

Table 1.—The chemotherapeutic value of insecticides for boxwood leaf miner larvae. Wakefield, R. I., July, 1949, to April, 1950.

Material[1]	Amount in 100 Gal. Water	Applications	Larvae per Leaf	Larvae Surviving
	lb.	*No.*	*No.*	*Per Cent*
Dieldrin 25% W	4.0	1	5.3	11.2
		2	4.4	11.5
Aldrin 25% W	4.0	1	4.7	30.8
		2	4.6	35.6
Nicotine sulfate 40%	2.5	1	4.8	65.5
		2	5.6	61.8
DDT 50% W	2.0	1	4.3	68.0
		2	3.6	61.5
Benzene hexachloride 50% W	2.0	1	4.1	70.4
Benzene hexachloride 50% W	2.0	1	4.7	62.1
Lindane 25% W	4.0	1		
Chlordane 50% W	2.0	1	4.0	71.9
Chlordane 50% W	2.0	1	5.1	69.0
Chlordane 40% W	2.5	1		
Check			4.6	76.7

Least significant difference at the 5% level—12.0%.

[1] In the first application, Tween 20 at the rate of 4 oz. in 100 gallons of water was included with each insecticide; in the second, 4 oz. of Triton B-1956 was used.

HOLLY LEAF MINER.—This insect is the most troublesome pest of holly in Rhode Island. Underhill (1943) has published an account of the life history of the insect in Virginia and, except for the time of appearance of the various stages, it corresponds to that observed in this state. During 1949 in Rhode Island, adults of the insect emerged in late May and early June. The bulk of the oviposition took place in June when the females deposited their eggs singly in deep punctures on the under surface of the leaves. The oviposition punctures are slit-like, the openings being about 0.1 millimeter in length, and heal within a short time. In developing its mine the larva feeds on the pallisade tissue beneath the upper epidermis. During the first instar the mine is linear and script-like, the larva being wholly enclosed by live plant tissue. In the second and third

Table 2.—**The chemotherapeutic value of several insecticides for holly leaf miner larvae. Wakefield, R. I., August, 1949, to April, 1950.**

Material[1]	Pounds in 100 Gal. Water	Linear Mines per Leaf	Blotch Mines per Leaf	Larval Survival
				Per Cent
Aldrin 25% W	4	10.5	.6	6.2
Dieldrin 25% W	4	10.3	.8	7.8
Lindane 25% W	4	10.5	8.6	82.0
Chlordane 40%	2.5	8.6	7.1	82.5
Check		9.1	8.5	92.6

Least significant difference at the 5% level—8.3%.

[1] Triton *B-1956* at the rate of 4 oz. in 100 gallons of water was included with each insecticide.

instars the larva continues to feed in the pallisade tissue, but the mine becomes blotch-like in appearance. On August 19, when the materials listed in table 2 were applied to American holly, *Ilex opaca*, the leaves were infested with first instar larvae, and their linear mines varied in length from 2.7 to 5.3 millimeters. Blotch mines were in evidence in some treatments in mid-September.

Four replicated trees averaging 8 feet in height were used in each treatment. When the sprays were applied it was observed that aldrin flocculated badly, while the other materials suspended well in water. During the period of April 6 to 9, 1950, when the insect was in the third instar, 100 random leaves from the trees in each treatment were removed and examined for larval mining activity. In certain of the treatments, in which the mines ended abruptly as short linear mines, the larvae had died. In other treatments, normal larval feeding had developed mines in which the blotch type was continuous with the linear. Live larvae were present in most of these.

The data presented in table 2 show that aldrin, dieldrin, lindane and chlordane were effective in preventing the development of holly leaf miner larvae inside of the leaves. Aldrin and dieldrin were considerably more effective chemotherapeutic than lindane and chlordane. When the examination was made, there were 46, 50, and 2,032 live larvae in the 400 leaves of the aldrin, dieldrin and check treatments, respectively. No counts were made of the numbers of live larvae in the leaves of the lindane and chlordane treatments.

BIRCH LEAF MINER.—This insect has increased in abundance during the past four years. It was numerous particularly during the season of 1950 when serious injury to the leaves of gray and white birch was experienced. In 1950 there were three generations of the insect in Rhode Island. Adults of the first generation appeared on May 10 and were abundant on May 12. They were observed in the field until June 12. Adults of the second generation were observed first on June 25, while those of the third were first found on July 27.

In an investigation of the life history and habits of the insect, Friend (1933) found that the preovipostition period of females in captivity was usually less than 24 hours. Field observations in Rhode Island substantiated these findings, for although the leaves of gray birch were 0.25 to 0.75 inch long on May 12, 2 days after the first adult flies emerged, eggs could be found imbedded in the leaf tissue.

The females deposit their eggs inside the leaf tissue by inserting the ovipositor through the cuticle and upper epidermis. The eggs are placed singly in the mesophyll a small scar forming over the incision in the upper epidermis. Shortly after deposition a small area of leaf surrounding the egg appears to cease growth and become slightly wrinkled. After hatching from the egg the larva mines the entire mesophyll. At first the mine is somewhat kidney-shaped. In later stages of larval development a blotch type of mine is excavated. Until the larva leaves the mine to pupate, it is enclosed by the cuticle and epidermis of both surfaces of the leaf.

Gray birch trees, *Betula populifolia*, 8 to 10 feet tall, in an area containing large numbers of the adult birch leaf miner, were used in two experiments involving the first and second generations. Utilizing May 10, the date of emergence of adults of the first generation, as a date of origin, the materials and concentrations listed in table 3 were applied 2, 12, and 23 days thereafter. Each of the insecticide treatments and the unsprayed check consisted of four replicated trees. Some treatments received three applications, while some were sprayed once or twice, as indicated. During each of the two periods, June 12 to 18 and June 29 and 30, 100 random leaves from the trees in each treatment were examined for live larvae, or for mines in which larval development had been completed. The leaves examined were the basal first or second ones on a growing tip. Certain of the treatments, for which no data are presented in table 3, were

Table 3.—The chemotherapeutic value of several insecticides for first generation birch leaf miner larvae. Slocum, R. I., May—June, 1950.

Material[1]	Pounds in 100 Gal. Water[2]	Applications	Days After Adult Emergence	Leaves with Live Larvae	
				6–12 to 6–18	6–29 to 6–30
Aldrin 25% W	4	1	12	1.5%	6.0%
	2	1	12	35.3	54.0
	1	1	12	51.3	64.5
	4	1	23	0.0	19.0
	2	1	23	0.3	20.5
	1	1	23	4.5	27.0
	4	2	12, 23	0.0	0.8
	2	2	12, 23	0.0	0.5
	1	2	12, 23	0.0	2.3
Dieldrin 25% W	4	1	12	0.0	2.5
	2	1	12	0.0	7.5
	1	1	12	0.3	9.3
	4	1	23	0.0	2.8
	2	1	23	0.0	11.5
	1	1	23	0.0	6.3
	4	2	12, 23	0.0	2.3
	2	2	12, 23	0.0	5.8
	1	2	12, 23	0.0	9.0
Nicotine sulfate 40%	1	2	2, 12	14.0	23.0
	1	2	12, 23	0.5	1.8
	1	3	2, 12, 23	0.3	2.5
Chlordane 40% W	2.5	2	2, 12	85.8	—
	1.25	2	2, 12	96.0	—
	2.5	2	12, 23	8.3	20.5
	1.25	2	12, 23	33.8	40.5
	2.5	3	2, 12, 23	8.8	20.0
	1.25	3	2, 12, 23	32.8	42.5
DDT 50% W	2	2	2, 12	86.0	—
	1	2	2, 12	89.3	—
	2	2	12, 23	90.0	—
	1	2	12, 23	96.0	—
	2	3	2, 12, 23	84.5	—
	1	3	2, 12, 23	90.8	—
Check				96.5	99.5

Least significant difference at 5% level for 6–12 to 6–18 period—7.0%
Least significant difference at 5% level for 6–29 to 6–30 period—5.5%

[1] *Triton B-1956* at the rate of 4 oz. in 100 gallons of water was included with each application of insecticide.
[2] Nicotine sulfate was used at one pint in 100 gallons of water.

not examined on June 29 or 30.

The data presented in table 3 show that nicotine sulfate, aldrin, dieldrin and chlordane were effective as chemotherapeutics for birch leaf miner larvae. Friend (1933) has recommended that for the control of the first generation two applications of nicotine sulfate at the rate of 1 to 1000 be made a week apart, beginning about 10 days after the first adults appear. Also, Friend (1933) has shown that nicotine sulfate acts as an ovicide against eggs of the birch leaf miner. In the studies reported herein no data were obtained relative to the ovicidal properties of any of the materials. It was found, however, that nicotine sulfate as well as aldrin, dieldrin and chlordane acted as larvicides.

One pint of nicotine sulfate in 100 gallons of water applied 2, 12, and 23 days, or 12 and 23 days after adult emergence was equally effective in killing the larvae. Two sprays of the material applied 2 and 12 days after adult emergence resulted in 23 per cent of the leaves with live larvae, while only 1.8 per cent of the leaves sprayed 12 and 23 days after emergence contained live larvae. Between the two examination periods there was little change in the degree of control obtained in the nicotine sulfate treatments, except where the material was applied twice, at 2 and 12 days after adult emergence. In this treatment there was an increase from 14 to 23 per cent infested leaves.

Two applications of wettable 25 per

cent aldrin at the rate of 1, 2 or 4 pounds in 100 gallons of water, applied 12 and 23 days after adult emergence, were equally effective in both examination periods. None of the leaves contained live larvae during the period of June 12 to 18, while 0.5 to 2.3 per cent were infested on June 29 and 30.

There was a difference in the degree of control obtained with 1, 2 and 4 pounds of the material applied 12 days after adult emergence, 4 pounds of 25 per cent aldrin being considerably more effective than either of the two lower concentration. Between examination periods there was an increase in the per cent of leaves infested with live larvae, particularly in the two treatments receiving 1 and 2 pounds of the material.

There was no appreciable difference between 1, 2, and 4 pounds of 25 per cent aldrin, applied 23 days after adult emergence. During the first examination period 0.0 to 4.5 per cent of the leaves in the 3 treatments were infested with live larvae. On the second examination date, the degree of infestation had increased at a regular rate among treatments, amounting to 19.0 to 27.0 per cent.

There was no appreciable difference in 1, 2 or 4 pounds of 25 per cent dieldrin applied once, at 12 or 23 days, or twice at 12 and 23 days after adult emergence. When examined first, there was 0.0 to 0.3 per cent of the leaves in the several treatments infested with live larvae. The second examination showed a fairly uniform rate of infestation ranging from 2.3 to 11.5 per cent according to the concentration of material applied.

Two applications of wettable 40 per cent chlordane, at the rate of 2.5 and 1.25 pounds in 100 gallons of water, made 2 and 12 days after adult emergence had little or no effect on the larval infestation of the leaves. When the material was applied later in the season, 12 and 23 days and 2, 12, and 23 days after adult emergence, there were fewer leaves infested with live larvae. The material acted as a chemotherapeutic but was less effective than nicotine sulfate, aldrin or dieldrin.

During the first examination period DDT exhibited a chemotherapeutic effect at the 2 pound rate of application. However, the material was less effective than any of the other insecticides investigated. No data on its effectiveness were obtained during the second examination period.

Table 4.—The chemotherapeutic value of several insecticides for second generation birch leaf miner larvae. Slocum, R. I., July–August, 1950.

MATERIAL[1]	AMOUNT IN 100 GAL. WATER	APPLICATIONS	DAYS AFTER ADULT EMERGENCE	LEAVES WITH LIVE LARVAE
		No.	*No.*	*Per Cent*
40% Nicotine sulfate	1 pt.	3	10, 17, 24	2.4
		2	10, 17	8.3
		1	10	29.5
40% Chlordane WP	2.5 lbs.	3	10, 17, 24	18.2
		2	10, 17	21.2
		1	10	25.9
25% Aldrin WP	2 lbs.	3	10, 17, 24	0.0
		2	10, 17	1.7
		1	10	22.0
25% Dieldrin WP	2 lbs.	3	10, 17, 24	0.0
		2	10, 17	0.0
		1	10	6.3
Check				96.3

[1] *Triton B-1956* at the rate of 4 oz. in 100 gallons of water was included with each application of insecticide.

Utilizing June 25, the date when the adults of the second generation appeared first, as a date of origin, the materials listed in table 4 were applied 10, 17 and 24 days thereafter. Each insecticide treatment and the unsprayed check consisted of 3 replicated trees. As in the first experiment, some of the trees were sprayed once, while some were sprayed two or three times as indicated. During the period of July 29 to August 5, the terminal two leaves on 50 random twigs from the trees in each treatment were examined for live larvae, or for mines in which larval development had been completed.

As shown in table 4, all materials were effective in controlling birch leaf miner larvae inside of the leaves. The descending order of effectiveness was dieldrin, aldrin, nicotine sulfate and chlordane.

In late July, in examining the foliage of trees included in the first experiment, it was found that the terminal leaves on trees in all treatments were infested with second generation larvae as severely as those on unsprayed trees. None of the chemotherapeutics effective against larvae of the first generation were of value against those of the second generation in leaves produced on the same trees later in the season.

DISCUSSION.—In a study of this type there are several factors that may influence the chemotherapeutic effect of the insecticides investigated. Among these are the gross structure and physiology of the host plant leaves, the nature of the insect mine produced, the mode of entry of the

insecticide into the leaf, and the physical and chemical properties of the insecticides.

In regard to the leaf structure and physiology of the three host plants included in the study, there is little information available at this time that would be of value in a comparison. Perhaps the most significant item is that the investigations were carried out on birch when the leaves were developing in gross structure, and on boxwood and holly 7 to 12 weeks after such development had been completed.

The nature of the mine or gall produced by the insects might have influenced the chemotherapeutic effectiveness of the insecticides. As far as protection by a barrier of plant tissue is concerned, the birch leaf miner is the most vulnerable of the three insect species. In its feeding activities the entire mesophyll is consumed, leaving only the epidermis and cuticle both above and below for protection. At the other extreme, the boxwood leaf miner is protected by the pallisade tissue, epidermis and cuticle above, and the spongy tissue, epidermis and cuticle below. Since the holly leaf miner feeds on the pallisade tissue, it is protected below by the spongy tissue, epidermis and cuticle, and by the epidermis and cuticle above.

There are three modes by which materials deposited on the surface of a leaf may reach the interior. Reference is made to: (1) diffusion in aqueous solution through the cuticle and epidermis; (2) solution and diffusion in the lipid phase through the cuticle and epidermis; and, (3) diffusion in the vapor phase through the stomata. All of the materials, except nicotine sulfate, are relatively water insoluble. From the best information available, the chlorinated hydrocarbon insecticides are soluble in water to the extent of 10 parts per million or less. Therefore, none of these would be expected to enter in aqueous solution. It is conceivable that nicotine sulfate could enter by all three methods and the chlorinated hydrocarbons by the second or third methods or a combination thereof. However, regardless of the method or methods by which the materials acted, the fact that certain of them were capable of killing insects wholly enclosed by plant tissue places them in the category of chemotherapeutants.

SUMMARY.—During 1949 and 1950, the relative chemotherapeutic value of nicotine sulfate and several chlorinated hydrocarbon insecticides was investigated in field tests involving three species of leaf mining insects, the larvae of which develop wholly within the host leaves.

Aldrin, dieldrin, nicotine sulfate, DDT, benzene hexachloride and lindane acted as chemotherapeutics when applied to leaves infested with boxwood leaf miner larvae. While aldrin was less effective than dieldrin, both were considerably more effective than any of the other insecticides.

Aldrin and dieldrin were equally effective as chemotherapeutants for first instar holly leaf miner larvae inside of the host leaves. Chlordane and lindane exhibited a chemotherapeutic effect on larval mining activity, but it was considerably less than that obtained with aldrin and dieldrin.

Dieldrin, aldrin, nicotine sulfate and chlordane were effective chemotherapeutants for first and second generation birch leaf miner larvae inside the leaves of gray birch. The descending order of effectiveness was dieldrin, aldrin, nicotine sulfate and chlordane. DDT exhibited a slight chemotherapeutic effect, but it was considerably less than any other material investigated.

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Plum Curculio Control on Prunes[1]

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In recent years damage by the plum curculio, *Conotrachelus nenuphar* Herbst., has increased considerably in Erie County, Pennsylvania, and this insect is one of the most destructive pests of prunes and plums. It is not uncommon to find 20 to 40 per cent of the fruit damaged by this insect in commercial orchards. Data published by the following investigators: Smith (1948), Stearns & Warren (1948), Neiswander (1948), Diggers & Darley (1948), Cox (1949), Snapp (1949), Driggers (1950) Rings (1950), Chandler (1950) and Bobb (1950, show that a high degree of control of plum curculiao has been obtained with some of the organic insecticides. Experiments (Cox 1949) have shown that parathion and benzene hexachloride were more effective for control of plum curculio on prunes than lead arsenate. In the present studies parathion and benzene hexachloride together with certain organic insecticides were given further trials in comparison with the standard lead arsenate treatment. This paper is a summary of the results for 1949 and 1950.

METHODS AND MATERIALS.—The investigations were conducted in commercial prune orchards on the variety *Fellemburg* (Italian Prune). In the tests, large blocks in orchards were used for the treatments. The experiments were conducted only in orchards that were surrounded or bordered by ideal hibernating quarters for adult plum curculios and had been heavily infested the previous year. All treatments were replicated two times. The sprays were applied with a power sprayer using a single nozzle spray gun. All the spraying was done from the ground and from the outside of the trees. The procedure followed in taking data was to pick up the dropped fruit from six trees in the center of each plot. The dropped fruit was collected every 2 days for a period of 4 weeks. The collected fruits were suspended over water in cloth mesh bags (one 0.125 inch mesh) and the larvae leaving the fruit dropped into the water. A record was kept of the number of larvae strained from the water.

The materials used in the experiments were as follows: lead arsenate, containing 19.50 per cent metallic arsenic and 58 per cent metallic lead; benzene hexachloride,[2] a wettable powder containing 10 per cent of the gamma isomer; parathion,[3] a wettable powder containing 25 per cent parathion; lindane,[4] a wettable powder containing 25 per cent lindane; a phosphorus compound,[5] containing 27 per cent ethyl p-nitrophenyl thionobenzenephosphonate; a phosphorus compound,[6] containing as active ingredient 33.4 per cent of a mixture of one part parathion and four parts methyl analogue of parathion, active ingredient designated as dialkyl nitroaryl thiophosphates; an oil,[7] viscosity 53 seconds Saybolt at 100° F., unsulfonated residue 93 per cent; a low soluble copper[8] containing 52 per cent metallic copper and wettable sulfur were used as fungicides; an emulsifying agent[9] containing pthalic anhydride of glycerol alkyl resin.

FIELD EXPERIMENTS.—During the season of 1949 the tests were conducted in two commercial orchards that were heavily infested with plum curculio. The sprays were applied on the following dates: first application at shuck split May 17, second application at shuck fall May 24 and the third spray June 4. The basic spray schedule used comprised three applications. However, the trees treated with lead arsenate received only two applications of spray. The results are summarized in table 1. As may be seen in table 1 lead arsenate did not give a high degree of control. Approximately 30 per cent of the dropped fruit was infested. Referring to the data in table 1 it is evident that benzene hexachloride, lindane, parathion and a split schedule of benzene hexachloride and parathion gave satisfactory control of plum curculio.

A list of the treatments for 1950 are given in table 2. All treatments received three applications of spray. The sprays were applied on the following dates: first application at shuck split, May 29, second

[1] Authorized for publication on December 29, 1950 as paper No. 1645 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

[2] *Gamtox*, California Spray-Chemical Corp., Richmond, Calif.

[3] American Cyanamid Co., New York, N. Y.

[4] *Isotox*, California Spray Chemical Corp., Richmond, Calif.

[5] *EPN-300*, E. I. duPont de Nemours and Co., Wilmington, Del.

[6] *Metacide*, Geary Chemical Co., New York, N. Y.

[7] *Gulf Oil 501*, Gulf Oil Corp., Pittsburgh, Pa.

[8] *Basic-Cop*, The Sherman Williams Co., Cleveland, Ohio.

[9] *Triton B-1956*, Rohm and Haas Co., Philadelphia, Pa.

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application at shuck fall, June 5 and the third application June 12. A summary of the results for 1950 are given in table 2. Lead arsenate did not effectively control plum curculio. Approximately 52 per cent of the droped fruit was infested. There was a light crop of fruit in the test orchards and this may have had some influence on the number of infested fruits. However, lindane, parathion, benzene hexachloride, ethyl p-nitrophenyl thionobenzene phosphonate, dialkyl nitroaryl thiophosphates, and a split schedule of benzene hexachloride and parathion greatly reduced the infestation in the dropped fruit. Although dialkyl nitroaryl thiophosphates gave satisfactory control of plum curculio, three applications of this insecticide injured the fruit. The injury was first observed as a red discoloration on the skin of the prunes and was more pronounced where the spray deposits accumulated. Later this injury appeared as russeted area on the fruit. No injury was observed on the foliage.

IMMATURE STAGES.—To determine the effect of certain insecticides on the immature stages of plum curculio, tests were conducted in neglected prune orchards. A list of the materials is given in tables 3 and 4. At the time the sprays were applied a large number of fruits were injured by plum curculio. An examination of the fruit showed approximately 50 per cent of the eggs had hatched. Some larvae were in the second and third instars and were well established in the fruit. The day after the sprays were applied a number of injured fruits were collected from the test plots. The collections were suspended over water in cloth mesh bags and the larvae leaving the fruit dropped into the water. The results for 1949 are summarized in table 3. Referring to the data in table 3 it may be seen that benzene hexachloride was quite toxic to the immature stages. Although parathion greatly reduced the number of curculio larvae that reached maturity it was not as effective for the immature stages as benzene hexachloride.

During the season of 1950 further tests were carried out with certain insecticides for the immature stages of plum curculio. A list of the treatments and a summary of the results are shown in table 4. It is evident from the data that benzene hexachloride and dialkyl nitroaryl thiophosphates were the most effective materials used to kill the immature stages in the fruit. The addition of an oil spreader-sticker appeared to increase the efficiency of benzene hexachloride. One application of dialkyl nitroaryl thiophosphates was quite toxic to the immature stages. No larvae were recovered from fruit that was treated with this insecticide. Although sprays of parathion and ethyl p-nitrophenyl thionbenzenephosphonate greatly reduced the number of larvae in the fruit they were not as effective for the immature stages as benzene hexachloride. To secure further information on how the various insecticides affect plum curculio control a sample of 100 fruits was taken from the test trees. The collections were held in an outdoor insectary for 10 days. At the end of this period the fruits were carefully dissected. The results are given in table 5. Referring to the data in table 5 it is evident that benzene hexachloride and

Table 1.—Results of field experiments for plum curculio control 1949.

TEST NO.	MATERIAL AND AMOUNTS PER 100 GALLONS[1]	APPLICATIONS	NO. LARVAE RECOVERED PER 100 FRUITS
1	Lead arsenate, 2.5 lbs. Oil,[2] 1 qt.	2 & 3	30.5
2	10% benzene hexachloride, 2.5 lbs. Oil, 1 qt.	1, 2 & 3	3.8
3	25% lindane, 1 lb. Oil, a qt.	1, 2 & 3	3.5
4	10% benzene hexachloride, 2.5 lbs. 25% parathion, 1 lb.	1 & 2 3	2.2
5	25% parathion, 1 lb.	1, 2 & 3	0.8
6	10% benzene hexachloride, 2.5 lbs.	1, 2 & 3	1.0
7	25% parathion, 1 lb.	1, 2 & 3	2.0

[1] In Test Nos. 1, 2 and 3 to each 100 gallons of spray was added one pound of low soluble copper and two pounds hydrated lime. In Test Nos. 4, 5, 6 and 7 to each 100 gallons of spray was added 6 pounds of wettable sulfur.
[2] Oil 9 parts and 1 part of *Triton B-1956*.

Table 2.—Results of field experiments for plum curculio control 1950.

TEST NO.	MATERIAL AND AMOUNTS PER 100 GALLONS[1]	APPLICATIONS	NO. LARVAE RECOVERED PER 100 FRUITS
1	Lead arsenate, 2.5 lbs. Oil,[2] 1 qt.	1, 2 & 3	52.6
2	10% benzene hexachloride, 2.5 lbs. 25% parathion, 1 lb.	1 & 2 3	1.1
3	25% parathion, 1 lb.	1, 2 & 3	0.5
4	10% benzene hexachloride, 2.5 lbs. Oil, 1 qt.	1, 2 & 3	1.7
5	25% parathion, 1 lb.	1, 2 & 3	0.8
6	Dialkyl nitroaryl thiophosphates (33.4% emulsion), 1 pt.	1, 2 & 3	0.5
7	25% parathion, 1 lb.	1, 2 & 3	0.8
8	Ethyl *p*-nitrophenyl thionobenzenephosphonate (27%), 1 lb.	1, 2 & 3	0.4
9	25% Lindane, 1 lb. Oil, 1 qt.	1, 2 & 3	1.5

[1] In Test Nos. 1, 4 and 9, to each 100 gallons of spray was added one pound of low soluble copper and two pounds of hydrated lime In Test Nos. 2, 3, 5, 6, 7 and 8, to each 100 gallons of spray was added 6 pounds of wettable sulfur.
[2] Oil 9 parts and 1 part of *Triton B-1956*.

dialkyl nitroaryl thiophosphates were very effective against immature stages of plum curculio. Although parathion was quite effective, 14 per cent of the fruit contained live larvae. Ethyl p-nitrophenyl thionobenzenephosphonate was less effective than the other insecticides. With this material 50 per cent of the fruit contained live larvae. When the fruit was dissected it was observed that some of the eggs reached the black spot stage but failed to hatch in fruit treated with benzene hexachloride, parathion, ethyl p-nitrophenyl thionobenzene phosphonate and dialkyl nitroaryl thiophosphates. The hatch was normal in the untreated fruit from the check trees.

RESIDUAL ACTIVITY.—During the season of 1949 peach trees were sprayed with parathion at the rate of 0.25 pound to 100 gallons. When the spray was thoroughly dry wire screen cages containing 25 adult plum curculios were placed over treated branches. After the beetles had had been exposed to the treated foliage for 24 hours the cages were removed from the trees and a record made of the number of curculios dead. The tests showed that the initial toxicity of parathion was quite high. After two days the treated foliage was not toxic to plum curculio adults. During the season of 1950 the tests were continued to obtain further information on parathion as well as other insecticides against plum curculio adults. A list of the treatments are given in table 6. The materials were applied to peach foliage with a power sprayer. The spray was thoroughy dry before wire screen cages were placed placed over treated branches. Twenty-five plum curculio adults were used in each test. In all the tests the beetles were exposed to the treated foliage for 24 hours. A summary of the results are given in table 6. Although benzene hexachloride appears to kill some of the adults the residual activity is of short duration. The initial toxicity of parathion, dialkyl nitroaryl thiophosphates and ethyl p-nitrophenyl thionobenzenephosphonate was at a high level. The residual effects of parathion and dialkyl nitroaryl thiophosphates appear to be of short duration. The tests indicate that sprays of ethyl p-nitrophenyl thionobenzenephosphonate are toxic to plum curculio adults for a period of 4 to 6 days.

Table 3.—Results of one application of insecticides for immature stages of plum curculio in prunes 1949. Application made June 8 and samples collected June 9.

MATERIAL AND AMOUNTS PER 100 GALLONS[1]	NO. FRUIT IN SAMPLE	NO. LARVAE RECOVERED PER 100 FRUITS	PER CENT REDUCTION
25% parathion, 1 lb. 10% benzene hexachloride, 2.5 lbs. Oil,[2] 1 qt.	900	10.6	83.7
Check, no spray	810 865	0.24 71.3	99.6 —

[1] To each 100 gallons of parathion spray was added 6 pounds of wettable sulfur. To each 100 gallons of benzene hexachloride spray was added one pound of low soluble copper and two pounds of hydrated lime.
[2] Oil 9 parts and 1 part of *Triton B-1956*.

TASTE TESTS.—During the season of 1949 ripe fruit was taken at random from prune trees that had received treatment numbers 1 to 5, table 1. The fruit was processed in the laboratories of one of the

Table 4.—Results of one application of insecticides for immature stages of plum curculio 1950. Applications made June 15 and samples collected June 16.

Test No.	Material and Amounts per 100 Gallons[1]	Fruits in Sample	Larvae Recovered 100 Fruits	Per Cent Reduction
1	10% benzene hexachloride, 2.5 lbs. Oil,[2] 1 qt.	1460	.068	99.9
2	10% benzene hexachloride, 2.5 lbs.	1479	1.15	98.8
3	25% parathion, 1 lb.	1550	10.77	89.2
4	Ethyl p-nitrophenyl thionobenzenephosphonate (27%), 1 lb.	1583	27.8	72.2
5	Dialkyl nitroaryl thiophosphates (33.4%) emulsion, 1 pt.	1404	0.0	100
6	Check, no spray	1550	100	—

[1] In Test Nos. 1 and 2, to each 100 gallons of spray was added one pound of low soluble copper and 2 pounds of hydrated lime. In Test Nos. 3, 4 and 5, to each 100 gallons of spray was added 6 pounds of wettable sulfur.
[2] Oil 9 parts and 1 part of *Triton B-1956*.

commercial processing plants. The procedure was as follows: (1) fruit washed in water 120° F.; (2) the fruit was then drained and packed in number 2 enameled cans; (3) cans were filled with a 30 per cent hot sugar syrup; (4) the cans were then sealed and processed 30 minutes in a hot water bath 210° F.; (5) the cans were cooled in running tap water immediately after processing.

The taste tests for off-flavor were made approximately two months after the fruit was processed. Certain individuals, of the executive and research staffs of some of the commercial processing plants in the vicinity of North East, Pennsylvania and Westfield and Fredonia, New York as well as students attending G. I. Training School at North East and at Harbor creek, Pennsylvania, tasted the processed fruit for off-flavor. To summarize the results of the taste tests briefly it may be said that a large percentage of the people could not detect any off-flavor in the fruit from the experimental plots. However, approximately 20 per cent of the tasters scored the prunes that had received three applications of benzene hexachloride as off-flavor. A few individuals remarked that the fruit tasted similar to prunes that had been picked up from the ground. No off flavor was found in prunes that received sprays of lead arsenate, parathion, lindane and a split schedule of benzene hexachloride in the first and second sprays followed by parathion in the last spray. During the season of 1949 the last application was made June 4.

Discussion.—The results of field experiments show that sprays of lead arsenate are not entirely satisfactory for control of plum curculio on prunes. Three applications of this material did not give adequate

Table 5.—Results of one application of insecticide for plum curculio 1950. 100 fruits dissected.

Test No.	Material and Amounts per 100 Gallons[1]	Per Cent Fruit Containing: Unhatched Eggs[2]	Larvae: Dead	Larvae: Living	No. Eggs or Larvae
1	10% benzene hexachloride, 2.5 lbs. Oil,[3] 1 qt.	8	78	0	14
2	10% benzene hexachloride, 2.5 lbs.	2	74	10	14
3	25% parathion, 1 lb.	10	66	14	10
4	Ethyl p-nitrophenyl thionobenzenephosphonate (27%), 1 lb.	4	34	50	12
5	Dialkyl nitroaryl thiophosphates (33.4%), 1 pt.	8	88	0	4
6	Check, no spray	0	0	92	8

[1] In tests nos. 1 and 2, to each 100 gallons of spray was added one pound of low soluble copper and two pounds of hydrated lime In tests nos. 3, 4 and 5, to each 100 gallons of spray was added 6 pounds of wettable sulfur.
[2] Eggs in black spot stage.
[3] Oil 9 parts and 1 part of *Triton B-1956*.

Table 6.—Residual activity of insecticides against plum curculio adults.

Material and Amounts per 100 Gallons	Per Cent Kill				
	Days After Treatment				
	0	1	2	4	6
10% benzene hexachloride, 2.5 lbs.	26	0	0	—	—
Ethyl p-nitrophenyl thionobenzenephosphonate (27%), 1.5 lbs.	100	100	100	50	18
Ethyl p-nitrophenyl thionobenzenephosphonate (27%), 1 lb.	100	100	90	40	—
Dialkyl nitroaryl thiophosphates (33.4% emulsion), 1 pt.	100	100	12.5	0	—
25% parathion, 1 lb.	100	100	13	0	—
Check, no spray	0	0	0	0	0

protection in heavily infested orchards. Benzene hexachloride, used at the rate of 0.25 pound of the gamma isomer to 100 gallons, gave excellent control of plum curculio. This material does not appear to be effective for the adults but is quite toxic to the immature stages of plum curculio. Although benzene hexachloride appears to give satisfactory control of plum curculio it is not entirely satisfactory for a spray on prunes. A full schedule of three applications of this material appears to produce an off-flavor in the processed fruit. The last spray was applied June 4 and the fruit was harvested September 10, 1949. Under field conditions parathion, used at the rate of 0.25 pound to 100 gallons, gave satisfactory control of plum curculio. This material appears to be more toxic to the adults and less effective against the immature stages than benzene hexachloride. No off-flavor has been detected in prunes treated with three applications of this material. Lindane appears to be as effective as benzene hexachloride for control of plum curculio and apparently does not produce any off-flavor in the fruit. During the season of 1950 sprays of ethyl p-nitrophenyl thionobenzenephosphonate gave excellent control of plum curculio. This material appears to be quite toxic to the adults and the residual activity lasts for several days. Tests indicate that this material is not as effective for the immature stages as benzene hexachloride. No injury to the fruit or foliage of prune has been observed where sprays of parathion, benzene hexachloride, lindane and ethyl p-nitrophenyl thionobenzenephosphonate were used. Tests for one season indicate that sprays of dialkyl nitroaryl thiophosphates are quite effective for control of plum curculio. This material appears to be quite toxic to the immature stages of plum curculio and the initial toxicity is at a high level to the adults. Although under field conditions dialkyl nitroaryl thiophosphates gave excellent control of plum curculio, three applications of this material injured prunes. At harvest time russeting of the fruit was quite pronounced.

SUMMARY.—Field experiments were conducted during the seasons of 1949 and 1950 in prune orchards comparing lead arsenate and certain organic insecticides for control of plum curculio. Lead arsenate, used at the rate of 2.5 pounds to 100 gallons, did not give satisfactory control of plum curculio. Benzene hexachloride, at the rate of 0.25 pound of the gamma isomer to 100 gallons, gave excellent control. This material was quite toxic to the immature stages but was of little value against the adults. Three applications of parathion at a concentration of 0.25 pound to 100 gallons gave excellent control of plum curculio. This material gave a high initial kill of the adults but was less toxic to the immature stages than benzene hexachloride. Tests for one season indicate that ethyl p-nitrophenyl thionobenzenephosphonate, used at the rate of 0.27 pound to 100 gallons, will give satisfactory control of plum curculio. This compound gave a high initial kill of the adults and the residual activity lasted from 4 to 6 days. It appears less toxic to the immature stages than parathion and benzenehexachloride. Experiments indicate that three applications of dialkyl nitroaryl thiophosphates are quite effective for control of plum curculio. This material gave a high initial kill of the adults but under field conditions the residual activity was of short duration. This material appears to be quite effective for the immature stages of plum curculio. No injury to the fruit or

foliage of prunes has been observed where sprays of benzene hexachloride, lindane, lindane, parathion and ethyl p-nitrophenyl thionobenzenephosphonate were used. Three applications of dialkyl nitroaryl thiophosphates injured the fruit of prune.

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Plum Curculio Control with New Organic Insecticides[1]

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Experiments with numerous new organic insecticides for the control of the plum curculio, *Conotrachelus nenuphar* (Hbst.) on peaches have been under way at Fort Valley, Ga., since 1946 (Snapp 1947, 1948, and 1949). The present paper reports the results of experiments with these insecticides conducted in 1949 and 1950. Most of the materials used were commercial products.

Because of the extremely mild winter of 1949–50 and late frosts, the trees in the experiments did not set a full crop. This crop was reduced one-half or more by a severe wind storm on June 7. Very few of the curculios that emerged from the soil early in the summer laid second-brood eggs. However, there were enough overwintered curculios still in the experimental orchards to cause a fairly severe infestation at harvest in plots not adequately protected.

ORCHARD EXPERIMENTS.—Both large-plot and small-plot experiments were conducted with several different sprays in 1950. All the sprays were applied with a conventional power sprayer, and most of them were applied four times—(1) at petal fall, (2) at shuck-off, (3) 2 weeks after shuck-off, and (4) 4 weeks prior to harvest. Hydrated lime 8 pounds[3] and zinc sulfate (36 per cent) 4 pounds were used with lead arsenate, which was applied in three sprays at petal fall, shuck-off, and 4 weeks before harvest. Wettable sulfur was used with all treatments in the applications made 2 weeks after shuck-off and 4 weeks before harvest. Except for TM-1 all materials were wettable powders containing the proportions of active ingredient indicated in the tables or in the text. When the fruit was harvested, samples of every fifth peach of each picking from four record trees in each replicate of the large-plot experiments, and all or samples from each tree of the small-plot experiments were cut open to determine the percentage infested with the plum curculio.

Large-Plot Tests.—Parathion, benzene hexachloride and lead arsenate in a split schedule, and chlordane were compared with lead arsenate in experiments conducted on the Elberta variety under

[1] Presented at the meeting of the Cotton States Branch of the American Association of Economic Entomologists at Memphis, Tenn., Feb. 5–7, 1951.
[2] Julius P. Hollon assisted in all experiments reported in this paper.
[3] In this paper all quantities of insecticides are for 100 gallons of spray.

commercial peach-orchard conditions. There were five replicates of each treatment in a latin-square set-up of plots, each of which contained 36 trees. The results of these tests are given in table 1.

Small-Plot Tests.—Each of 15 treatments and a check were replicated seven times on single-tree plots in a randomized set-up on the Early Elberta variety. The insecticides used and the results obtained were as shown in table 2. The first 5 treatments were the same as those used for the large-plot tests, and in both series of tests parathion was the most effective treatment.

CAGE TESTS.—Twelve series of cage tests with plum curculio adults were conducted from April to July in 1949 and in 1950. The method employed was the same as described in a previous paper (Snapp 1947). Single trees were sprayed with the experimental materials; cylindrical screen cages were then placed over branches and curculios introduced. The full details of these tests will not be given. The results, however, are summarized in the following paragraphs.

These tests showed that newly emerged first-generation adult curculios are more resistant to most insecticides than overwintered adults.

The results with parathion were in line with those of the field tests. Three pounds of 15 per cent wettable powder killed all the overwintered and new first-generation adults within 3 or 4 days in every test. Two pounds was practically as good. When only 1 pound of 15 per cent parathion was combined with 2 pounds of lead arsenate, all the overwintered and new beetles were killed within 2 to 5 days in all tests except one, where it was 92 per cent. Parathion had fairly good residual value up to 10 days after application.

The results of cage tests conducted in 1950 confirmed those of 1948 and 1949 in showing that, when compared on the basis of equivalent gamma content,

Table 2.—Results of experiments with various insecticides on small plots for control of the plum curculio on peaches, 1950.

MATERIAL (POUNDS PER 100 GALLONS)	NUMBER OF APPLICATIONS	PER CENT OF INFESTED FRUIT
Parathion (15%) 3	4	3
	5[1]	2
Benzene hexachloride (6% gamma) 4 Lead arsenate 2	2 2	11
Chlordane (40%) 3.75	4	6
Lead arsenate 2	3[2]	7
Lindane (25%) 1	4	9
Benzene hexachloride (6% gamma) 4	4	5
Chlordane (40%) 2.5	4	12
Aldrin (25%) 2	4	1
Dieldrin (25%) 2	4	0
Methoxychlor (50%) 2	4	5
Lead arsenate 2+DDT (50%) 2	3[2]	6
TM-1 (25% emulsible)[3]	4	21
DFDT[4] 4	4	27
Parathion (15%) 3 TM-2[5] 2	3 1	0
Untreated	—	46

[1] Fifth application made 2 weeks before harvest.
[2] Applications made at petal fall, shuck-off, and 4 weeks before harvest.
[3] A product containing a 1:2 mixture of 1,1-bis(*p*-chlorophenyl)-2-nitropropane and 1,1-bis-(*p*-chlorophenyl)-2-nitrobutane. Used at 1 part in 600 parts of water. (*Dilan*)
[4] A product containing 25% of 1,1,1-trichloro 2,2-bis(*p*-fluorophenyl) ethane.
[5] A product containing 27% of O-ethyl O-*p*-nitrophenyl benzenethiophosphonate and referred to herein as TM-2 ("*EPN*")

Table 1.—Results of orchard experiments with insecticides on large-scale plots for control of the plum curculio on peaches, 1950.

MATERIAL (POUNDS PER 100 GALLONS)	APPLICATIONS	MEAN NUMBER OF DROPS	INFESTED DROPS (MAY 8–15)	INFESTED FRUIT AT HARVEST
Parathion (15%) —3	4	19	1%	8%
	5[1]	19	3	1
Benzene hexachloride (6% gamma) 4 Lead arsenate —2	2 2	24	7	6
Chlordane (40%) —3.75	4	16	28	6
Lead arsenate —2	3	89	73	21
Difference required for significance:				
1%		26	12	6
5%		19	9	5

[1] Fifth application made 2 weeks before harvest.

lindane or other forms of high gamma benzene hexachloride are not so effective as the technical material. The 6 per cent gamma material, 4 pounds, killed 90 per cent of new first-generation adults within 13 days, whereas the 25 per cent gamma material, 1 pound, killed only 10 per cent within that time and only 50 per cent within 23 days. A similar difference was suggested by the orchard tests on single-tree plots.

Methoxychlor showed fairly good residual value. In 1950, 2 pounds of a 50 per cent wettable powder killed all overwintered adults within 3 to 7 days and all new first-generation adults within 13 days.

Aldrin and dieldrin gave consistently good results in both 1949 and 1950. In 1950 2 pounds of 25-per cent wettable powder killed all overwintered and new first-generation adults within 3 or 4 days in every test. Both materials showed considerable residual value. In 1950 aldrin killed 76 per cent of new first-generation adults within 7 days after it had been on the tree 10 days. Dieldrin at the rate of 6.66 pounds of 15 per cent wettable powder killed 100 per cent of new first-generation adults within 3 days after it had been on the tree 1 week, 100 per cent within 7 days after it had been on the tree 2 weeks in one test, 80 per cent within 12 days after it had been on the tree 2 weeks in another, and 80 per cent within 15 days after it had been on the tree 27 days.

TM-2 gave striking results in 1950. Two pounds of 27 per cent wettable powder killed all overwintered and new first-generation plum curculio adults within 2 to 5 days. It also seems to have exceptional residual value.

TM-3,[1] a product containing a 1:4 mixture of parathion and its methyl homolog (0,0-dimethyl 0-*p*-nitrophenyl thiophosphate) at the rate of 7.68 ounces of a 30 per cent emulsion concentrate per 100 gallons killed all overwintered and new first-generation plum curculio adults within 2 to 5 days.

Chlordane was moderately effective. In 1950 2.5 or 3.75 pounds of a 40 per cent wettable powder killed all overwintered adults within 3 to 7 days and all new first-generation adults within 6 to 13 days. It showed good residual value. Also in 1950 3.75 pounds of a 40 per cent wettable powder killed all overwintered adults within 7 days after it had been on the tree 10 days, and all new first-generation adults within 10 days after it had been on the tree 6 days.

TM-1, 1 pound of a 50 per cent wettable powder, gave inconsistent results, although most of them were favorable. The emulsifiable TM-1 at 1:600 gave poor results, as it did in the tests on single trees. Of the two ingredients, the nitrobutane derivative was less effective.

Insecticide 4049,[2] S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate, 2 pounds of 25 per cent wettable powder, killed all overwintered and new first-generation plum curculio adults within 2 to 4 days. An emuslion of that material gave very good results against overwintered adults but only fair results against new first-generation adults.

Insecticide 4124, containing dimethyl-*o*-chloro-*p*-nitrophenyl thiophosphate, in the proportion of 1 part of 25 per cent emulsion concentrate to 600 parts of water, gave good results against overwintered adults but not too good results against new first-generation adults.

Insecticide C-1014,[3] containing octamethyl pyrophosphoramide, applied on the tree, on the ground, or by dipping branches in it, was ineffective against plum curculio adults. One pound of a 66 per cent formulation per 100 gallons was used on the tree and for dipping branches; 2 pounds was used for ground applications.

As usual lead arsenate was slow in killing plum curculio adults. The addition of DDT to lead arsenate improved the results and accelerated the action somewhat.[4]

TREATMENT OF SOIL WITH CHLORDANE AND PARATHION.—In experiments conducted in 1949 chlordane and parathion were effective against plum curculio larvae in the soil and parathion was effective against the pupae. Only 0.8 per cent of the larvae emerged as adults where 6 pounds of 50 per cent chlordane was used at the rate of 1 gallon per 6 square yards of soil 5 or 6 days after the larvae entered the soil. Where 6 or 8 pounds of 25 per cent parathion

[1] *Mutacide.*
[2] An experimental formulation furnished by the American Cyanamid Company.
[3] An experimental formulation furnished by the Dow Chemical Company.
[4] All analyses were made by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine.

Table 3.—Analyses of insecticide residues on peaches from experimental plots, 1949 and 1950.

MATERIAL (POUNDS PER 100 GALLONS)	APPLICATIONS	DATE LAST APPLICATION	DATE SAMPLED	RESIDUE (P.P.M.)
1949				
				Organic Chlorine
Benzene hexachloride (6% gamma) 4	4	June 13	July 11	0.50
		22	20	0.23
	3	May 4	11	0.13
(25% gamma) 1	4	June 13	11	0.08
Chlordane (50%) 2	4	June 13	July 11	0.07
3	4	14	11	0.14
3	4	22	20	0.40
Methoxychlor (50%) 2	4	June 22	July 20	1.17
DDT (50%)[1] 2	3	June 22	July 20	0.84
				Parathion
Parathion (25%) 2	4	June 14	July 11	0.02
	4	22	20	0.03
	5	28	11	0.11
	3	22	20	0.03
				Arsenic Trioxide
Lead Arsenate 2	3	June 22	July 20	1.84
1950 (Large-Plot tests)				
				BHC
Benzene hexachloride (6% gamma) 4	2[2]	May 3	July 19	0.9
				Chlordane
Chlordane (40%) 3.75	4	June 20	July 19	3.2
				Parathion
Parathion (15%) 3	4	20	July 19	.11
	5	July 5	19	.26
				Arsenic Trioxide
Lead arsenate 2	2[3]	June 21	July 19	2.6
	3	20	19	2.7
1950 (Small-Plot tests)				
				BHC
Benzene hexachloride (6% gamma) 4	2[2]	Apr. 28	July 11	0.4
	4	June 13	11	2.2
				Lindane
Lindane (25%) 1	4	June 13	July 11	.7
				Chlordane
Chlordane (40%) 3.75	4	June 13	July 11	2.4
2.5	4	13	11	2.4
				Methoxychlor
Methoxychlor (50%) 2	4	June 13	July 11	9.9
				Parathion
Parathion (15%) 3	4	June 13	July 11	.08
2	5	27	11	37
				EPN
TM-2 (27%) 2	1[4]	June 13	July 11	.98
				Aldrin
Aldrin (25%) 2	4	June 13	July 11	.4
				Dieldrin
Dieldrin (25%) 2	4	June 13	July 11	1.9
				DDT
DDT (50%) 2+lead arsenate 2	3	June 13	July 11	6.9

[1] Lead arsenate included in spray.
[2] Lead arsenate used for last 2 sprays.
[3] Benzene hexachloride used for first 2 sprays.
[4] Parathion used for first 3 sprays.

were used at the same rate against larvae, 8.3 per cent and 5.3 per cent respectively, of the larvae emerged as adults. Where parathion was used against pupae in the soil, only 1 per cent emerged as adults where 8 pounds of the 25 per cent wettable powder was used at the rate of 1 gallon per 6 square yards of soil. Observations indicated that the plum curculio adults reared from larvae in soil sprayed with chlordane or parathion were affected by the treatment.

PERSISTENCE OF RESIDUES.—To determine the residues of the new insecticides on peaches at harvest time, a number of analyses were made of samples from two series of field plots treated in 1949 and 1950. The samples were composite ones taken from all replicates. The results of the analyses from both series of plots are given in table 3. The amounts of residue on the fruit sprayed with chlorinated compounds were calculated from organic-chlorine determinations corrected for the value found for the untreated check. It was not practical to determine the gamma isomer in the residues of the technical benzene hexachloride, so the results indicate total benzene hexachloride. The organic chlorine determinations calculated for aldrin and dieldrin give values that are too high, since the technical materials contained other chlorinated by-products of the manufacturing process. These values should therefore be regarded only as an indication of the theoretical maximum in these samples.

EFFECT OF NEW INSECTICIDES ON PEACH FRUIT, FOLIAGE, AND TREES.—In 1950 the flavor of fresh ripe peaches was affected by benzene hexachloride (6 per cent gamma), 4 pounds in each of four applications, the last one 4 weeks before harvest. There was no effect on the flavor of fresh ripe peaches in 1950 from the 6 per cent gamma material at the same rate in two applications, at petal fall and shuck off, the latter 80 days before harvest; or from lindane, 1 pound of a 25 per cent wettable powder in four applications, the last 4 weeks before harvest.

In 1949 the flavor of canned peaches was affected by benzene hexachloride (6 per cent gamma), 4 pounds at petal fall, shuck-off, and 2 weeks after shuck-off, the last one 68 days before harvest, and by lindane 1 pound of a 25 per cent wettable powder in four applications, the last one 4 weeks before harvest.

No injury to the fruit, leaves, budwood or any part of peach trees could be discerned from the other experimental applications of the materials listed in this paper except lead arsenate. With a safener, lead arsenate caused the usual amount of injury. Without a safener, it caused serious foliage and fruit injury and defoliation. Heavy foliage injury, heavy defoliation, and some fruit injury resulted from tetraethyl pyrophosphate fog applied by commercial airplanes to peach orchards for plum curculio control.

SUMMARY—In large-plot experiments conducted in peach orchards at Fort Valley, Ga., in 1950, nearly perfect control of the plum curculio was obtained at peach harvest from five applications of parathion, 3 pounds of 15 per cent wettable powder per 100 gallons. Fairly good results were obtained with four applications of parathion or of chlordane, and with a split schedule of benzene hexachloride and lead arsenate. The regular schedule of lead arsenate gave poor results, 21 per cent of the fruit becoming wormy.

Parathion and benzene hexachloride gave much better control of the plum curculio in peach drops than did chlordane and lead arsenate. In experiments on single-tree plots parathion placed first among the materials tested in both series of fields plots. Not a single infested peach was found on single-tree plots treated with dieldrin or a split schedule of parathion and EPN. Aldrin gave good control and methoxychlor showed promise.

In cage tests parathion, TM-2, insecticide 4049, methoxychlor, aldrin, dieldrin, and chlordane were effective against both over-wintered and new first-generation plum curculio adults. On a basis of equal gamma content, lindane was less effective than technical benzene hexachloride. TM-3 gave good results, but TM-1 and insecticides 4124 and C-1014 were comparatively ineffective. The residual value of TM-2 was exceptional, whereas that of dieldrin, methoxychlor, parathion, and chlordane was good.

The flavor of ripe fresh peaches was affected by benzene hexachloride and that of canned peaches by benzene hexachloride and lindane. Most of the new insecticides caused no injury to the fruit, leaves, budwood or any part of peach trees. Tetraethyl pyrophosphate fog caused heavy injury, heavy defoliation, and some fruit injury.

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Sidelights on European Red Mite Control

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The efficient and effective control of insect pests in apple orchards is a complicated operation. Many factors are involved, including the effects of the spray practices not only upon the pest to be controlled, but also upon other pests and diseases, upon beneficial organisms, upon the health of the trees, upon the quantity and quality of the fruit, and of course, upon the economics of apple production. All this is well known to every entomologist. In order to meet the demand for the thorough control of each pest as it becomes destructive in the orchard, however, the entomologist too often has been forced to recommend new insecticides or additional applications without full regard for the long-range effects of the treatments. As a result, apple growers generally are applying a complex schedule of sprays that appears to be nearing a point of maximum practical effectiveness. Recently, the use of a new insecticide or additional applications for the control of one pest, too often has been followed by an increase of some other, possibley even more destructive pest (Harman 1948, Chapman & Lienk 1950). Further to improve pest control practices, therefore, it is becoming increasingly important to study the long-range side-effects of the treatments recommended.

Over a period of 10 or 15 years, the author has observed that in well-sprayed apple orchards the trees frequently suffered destructive infestations of European red mite, while adjacent, unsprayed trees usually were practically free from mites. It seemed probable that the destruction of natural enemies promoted the development of the mites on the sprayed trees (Garman & Townsend 1938, Lord 1949, Pickett 1949, Lathrop & Hilborn 1950). The counter suggestion was made by some entomologist;, however, that the spray treatment did not promote the development of the mites, but instead, the foliage on the unsprayed trees was so severely injured by scab and various pests, the leaves could not support a large red-mite population.

To develop additional information on the direct and indirect effects of spray applications upon the European red mite and its natural enemies, an experiment was conducted in an orchard at Monmouth, Maine, through the season of 1950.

EXPERIMENTAL DESIGN. The experimental orchard consisted of 124 trees, about 30 years old, mostly McIntosh, with eight Red Delicious trees planted irregularly through the orchard as pollinizers. The orchard was on nearly level land, sloping gently to the southeast. It consisted of 18 rows, extending northeast and and southwest, with 10 trees in a row. Trees were missing irregularly throughout.

The entire orchard was given uinform treatment during the early season through the blossom period. During this antepetal-fall period, the object was to control scab so completely that for experimental purposes all fungicides could be omitted from some of the plots during the post-bloom period, without the development of destructive scab infection. The early season treatment (Table 1) consisted of 3 applications of sulphur to the trees, and also 3 ground sprays of sodium dinitro-ortho-cresol.[2]

Beginning with the petal-fall application the orchard was divided into 5 plots treated (Table 2) as follows throughout the rest of the season:

Rows 1 and 2.	No treatment of any kind.
Rows 3 to 7.	Lead arsenate only.
Rows 8 to 11.	*TM*-2[3] with lead arsenate.
Rows 12 to 14.	Bentonite-sulphur dust, with *TM*-2[3] and lead arsenate.
Rows 15 to 18.	Bentonite-sulphur dust with lead arsenate.

The ground sprays were applied with a conventional orchard sprayer, at 600 pounds pressure. Two men following the sprayer, each with a short, adjustable spray gun, applied the spray to the entire orchard floor. The grass and other ground cover showed temporary injury from the spray, but soon recovered.

The applications to the trees were made

[1] Bernie E. Plummer, Jr., Research Chemist, Maine Agr. Expt. Sta., cooperated in the project by determining the chlorophyll content of samples of apple leaves, and the sugar content of samples of apples. James W. Reynolds, Summer Assistant in Entomology, made the mite counts and other valuable contributions.

[2] *TM*-1 *Krenite 26*. 19% sodium dinotro-ortho-cresol. E. I. du Pont de Nemours & Co., Inc., Wilmington, Delaware.

[3] *TM*-2 Karathane WP-25. 22.5% Dinitro capryl phenyl crotonate, 2.5% other nitrogen derivatives of phenol chiefly dinitro capryl phenol. Rohm & Haas Co., Philadelphia 5, Penn.

[4] *TM*-3 Aramite-15 W. 15% chloroethyl butylphenoxy methyl ethyl sulphite. U. S. Rubber Co., New York 20, N. Y.

EASTERN BRANCH PROGRAM, 1950.

by means of a so-called liquid-duster.[1] The dust was applied in the conventional manner. The other materials were applied as concentrate mist spray in the liquid phase of the application.

RESULTS. Table 3 records the average numbers of mites and mite eggs per leaf, observed on full-sized, mature McIntosh leaves. The data are shown graphically in figure 1. All stages of the mites were counted. The counts were made from 100-leaf samples picked at random from the several treatments. When a count could not be completed in one day, approximately equal numbers of leaves from each treatment were counted each day.

Only two counts were made of leaves from the trees that received no post-bloom treatment. Frequent observations, however, showed that the mite population remained very low on the untreated trees The first count was made on August 10, when the mite population in the plot was was at its maximum.

The mite population on the foliage treated with sulphur dust and lead arsenate was slightly greater than on the other treatments even at the time of the first count, June 19. After mid-July, the population increased rapidly to a peak of 117 mites per leaf in mid-August. The peak was followed by a sharp decline in the population, which countinued through the rest of the season.

Where *TM-2* was used with the sulphur dust and lead arsenate, the redmite population remained moderately low through the month of July. After the spray applications were discontinued, however, the mite population increased sharply to a peak in mid-August, with an average of 51 mites per leaf. A sharp decline followed the peak, but during late August the mite population again increased and continued to rise through the period of observation. Probably some of the increased population on this plot, especially after the spray applications were discontinued, developed from mites drifting in from the adjoining plot treated with sulphur and lead arsenate without an acaricide.

On the plot treated through the post-bloom period with lead arsenate only, the red mite population was distinctly lower than on either of the sulphur-dusted plots. Here the peak of the mite population in mid-August was 28 mites per leaf. The peak was followed by the characteristic decline in the numbers of mites.

Where *TM-2* with lead arsenate was applied through the post-bloom period, there was a gradual increase in the mite population to a maximum of 15 mites per leaf early in September. At no time was there visible mite injury to the foliage.

The lowest population of mites was observed consistently on the trees that received no spray or dust treatment after bloom. A count of about 8 mites per leaf was made on August 10, after which the population declined.

LEAF INJURY—The red-mite population was slow in developing in the experimental orchard in 1950, with the peak in mid-August. In 1948 and in 1949 the peaks occurred during the last week of July. There was a corresponding delay in the development of mite injury to the apple foliage in 1950, and the mite injury never became quite so severe as it had been during the two preceding summers. The delayed build up of the mite population, and the comparatively light foliage injury, probably resulted largely from somewhat lower mean temperatures during the summer of 1950.

The injury to the foliage was most severe on the plot treated with sulphur and lead arsenate. Injury developed more slowly where TM-3 was added to the sulphur and lead arsenate, and the injury never became quite so severe where TM-3 was used.

The loss of chlorophyll (Table 4) proved to be an index of the degree of injury suffered by the leaves. Leaves from the sulphur-lead arsenate plot showed an average loss through the summer of practically 20 per cent of the chlorophyll compared to the plot receiving no treatment after bloom. Leaves from the sulphur-lead arsenate-*TM-3* plot showed a seasonal average loss of 16 per cent of the chlorophyll.

Table 1.—Ante-petal-fall treatments. Experimental McIntosh orchard, Monmouth, Maine, 1950.

DATE	TREATMENT[1]	DUST PHASE	LIQUID PHASE: Material in 30 Gal. Water
May			
12	Prepink	Bentonite sulphur	Lead arsenate—12 lb.
18	Pink	Bentonite sulphur	Dry lime sulphur—4 lb.
31	Mid-bloom	Bentonite sulphur	Water only

[1] In addition ground sprays of TM-1 (1 gal. in 100 gal. water) covering the entire area of the orchard floor were applied May 12, 18, 26.

[1] Niagara Cyclone liquid-duster 1948 model.

Table 2.—Post-bloom treatments. Experimental McIntosh orchard, Monmouth, Maine, 1950.

Date	Application	Liquid Phase: Material in 30 Gal. Water	Dust Phase	Liquid Phase: Material in 30 Gal. Water
Rows 1 and 2—No treatment throughout post-bloom period				
		*Rows 3 to 7**		*Rows 12 to 14*
June 2	Petal-fall	Lead arsenate 6 lb.	Bentonite sulphur	*TM-3* 3 lb. Lead arsenate 6 lb.
6	Oyster-shell scale	DDT 12 lb.	—	DDT 12 lb.
9	1st cover	—	Bentonite sulphur	*TM-3* 3 lb.
16	2nd cover	Lead arsenate 6 lb.	Bentonite sulphur	Lead arsenate 6 lb.
22	3rd cover	—	Bentonite sulphur	*TM-3* 3 lb.
29	4th cover	Lead arsenate 6 lb.	Bentonite sulphur	*TM-3* 3 lb. Lead arsenate 6 lb.
July 7	5th cover	Lead arsenate 8 lb.	Bentonite sulphur	*TM-3* 3 lb. Lead arsenate 8 lb.
15	6th cover	Lead arsenate 8 lb.	Bentonite sulphur	*TM-3* 3 lb. Lead arsenate 8 lb.
22	7th cover	—	—	—
Aug. 1	8th cover	Lead arsenate 8 lb.	Bentonite sulphur	*TM-3* 3 lb. Lead arsenate 8 lb.
		*Rows 8 to 11**		*Rows 15 to 18*
June 2	Petal fall	TM-2 3 lb. Lead arsenate 6 lb.	Bentonite sulphur	Lead arsenate 6 lb.
6	Oyster shell scale	DDT 12 lb.	—	DDT 12 lb.
9	1st cover	—	Bentonite sulphur	Water only
16	2nd cover	*TM-2* 3 lb. Lead arsenate 6 lb.	Bentonite sulphur	Lead arsenate 6 lb.
22	3rd cover	—	Bentonite sulphur	Water only
29	4th cover	*TM-2* 3 lb.	Bentonite sulphur	Lead arsenate 6 lb.
July 7	5th cover	*TM-2* 3 lb. Lead arsenate 8 lb.	Bentonite sulphur	Lead arsenate 8 lb.
15	6th cover	Same as 5th cover	Bentonite sulphur	Lead arsenate 8 lb.
22	7th cover	—	Bentonite sulphur	Water only
Aug. 1	8th cover	Same as 5th cover	Bentonite sulphur	Lead arsenate 8 lb.

* No dust applied to rows 3 to 7 and 8 to 11.

Table 3.—European red mites and eggs on fully developed, mature, McIntosh apple leaves, Monmouth, Maine, 1950. Average numbers per leaf.

	Treatment After Bloom									
	None		Lead Arsenate Only		*TM-2* with Lead Arsenate		Sulphur with *TM-3* and Lead Arsenate		Sulphur with Lead Arsenate	
Date	Mites	Eggs	Mites	Eggs	Mites	Eggs	Mites	Eggs	Mites	Eggs
June 19–20			.19	.46	0	0	.91	.55	2.24	1.96
26–28			1.03	.62	.25	.09	.56	.28	2.62	2.20
July 4– 5			.87	4.53	.06	.23	.35	3.90	2.58	17.53
10–11			2.57	7.93	.04	.51	.80	2.47	5.68	24.04
17–18			5.41	5.43	.14	.50	6.31	3.65	22.98	15.04
24–26			8.37	14.11	1.52	7.69	6.14	30.15	29.26	70.48
Aug. 1– 3			8.95	33.75	2.30	10.03	18.47	38.81	49.84	100.89
7–9			16.90	23.90	4.54	8.60	31.24	28.91	91.46	115.63
10	7.66	6.94								
14–16			28.13	24.85	9.41	12.55	51.11	49.99	117.80	95.93
21–23			16.25	34.08	9.30	20.55	36.93	68.68	90.53	94.37
25	3.62	9.70								
28–30			22.07	33.52	10.81	23.27	47.72	83.43	61.40	45.12
Sept. 4– 6			15.20	22.36	14.68	17.30	56.23	52.25	56.25	39.17

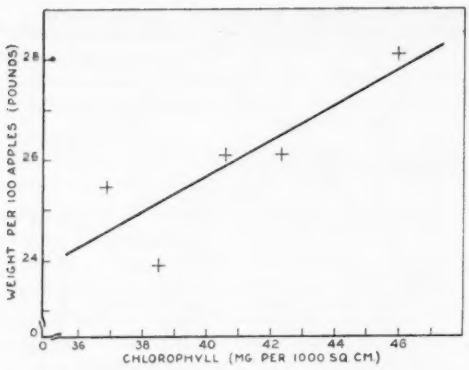

FIG. 1.—Correlation between the average chlorophyll content of apple leaves through the season, and the weight per 100 apples at picking time. The regression line, plotted by inspection, suggests a close dependence of the weight of apples upon the chlorophyll content of the leaves.

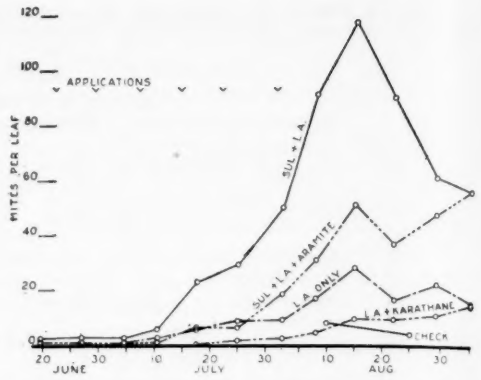

FIG. 2.—Populations of European red mite on full-sized, mature McIntosh apple leaves, from plots treated through the post-bloom period with sulphur and lead arsenate; sulphur, lead arsenate and *TM-3;* lead arsenate and *TM-2;* lead arsenate only; and no treatment (check) after bloom.

Where the trees were sprayed with only lead arsenate after bloom, the foliage injury was distinctly less than on the sulphur-dusted plots. There was an average seasonal reduction of about 12 per cent in the chlorophyll content of the leaves where lead arsenate only was applied. The general appearance of the trees was good.

On the plot treated with TM-2 and lead arsenate, there was no visible injury to the foliage, and the trees appeared to be in excellent condition. There was nevertheless, an average reduction of about 8 per cent in the chlorophyll content of the leaves.

Leaves from the trees that received no treatment after bloom appeared in a more vigorous state of health than the leaves from any other plot. The unsprayed leaves had the highest chlorophyll content. They seemed crisper, and had a different feel when handled. As shown in table 4, they weighed more per unit of surface area, than the leaves from the sprayed plots.

EFFECTS UPON THE FRUIT.—As might be expected, there is a distinct correlation between the red mite population on the leaves, the chlorophyll content of the leaves, and the size of the apples. The correlation between the chlorophyll content of the leaves and the weight per 100 apples at picking time is shown in table 4, and figure 2. The color and the sugar content of the fruit were also affected by the injury to the leaves. The average color of the apples at picking time was best on the fruit from the trees not sprayed after bloom. From the other plots, the degree of color on the fruit was inversely related to the severity of the injury to the leaves. The apples from the plot sprayed with lead arsenate alone were highest in total sugars (Table 4), and the total sugar content of apples from the other plots varied inversely with the degree of foliage injury. The sucrose content, which is an important factor in the flavor of the fruit, varied

Table 4.—Analyses of McIntosh apple leaves and fruit from the five treatments.

	LEAVES (1000 CM.²)		APPLES[3]		
POST-BLOOM TREATMENT	Weight[1] (Grams)	Chlorophyll[1] Content (Mg.)	Weight[2] per 100 apples (Lb.)	Total[3] Sugars (%)	Sucrose[3] (%)
None	20.46	45.98	28.10	8.79	2.17
Lead arsenate only	19.54	40.58	26.10	9.36	1.85
TM-2 with lead arsenate	19.48	42.43	26.15	8.63	2.17
Sulphur with *TM-3* and lead arsenate	19.09	38.49	23.90	8.60	1.84
Sulphur with lead arsenate	19.03	36.84	25.45	8.28	1.63

[1] Averages of 6 samples from each treatment, collected at intervals between July 26 and September 21.
[2] Calculated from weights of 500 apples from each treatment.
Analyses of flesh of peeled and cored apples.

in all plots directly with the chlorophyll content of the leaves.

SCAB CONTROL.—The present investigation is not concerned directly with the control of apple scab. Since the control of red mite and apple scab are so closely interralated, however, scab control has an important bearing.

Scab infection in the orchard generally was exceptionally light until mid-July. Evidence of infection increased during late July and in August. A count on August 26 showed the following percentages of leaf scab:

No spray after bloom	16
Lead arsenate only	9
TM-2-lead arsenate	8
Sulphur dust-lead arsenate	1
Sulphur dust-lead arsenate-TM-3	1

It is evident that the leaves were not very severely infected by scab on any of the plots. Even on the trees that received no treatment after bloom, scab injury to the leaves did not appear sufficient to account for the failure of a heavy red mite population to develop.

Examination at picking time revealed the following percentages of the apples infected with scab:

No spray after bloom	70
Lead arsenate only	31
TM-2-lead arsenate	12
Sulphur-lead arsenate-TM-3	1.4
Sulphur-lead arsenate	0.6

Much of the infection on the fruit was in the form of pin-point spots that developed late in the season. The scab spots on many of the apples were so small they would have escaped detection in a commercial pack. Some of the infection in the TM-2 plot probably drifted in from the adjoining plot sprayed with lead arsenate only.

NATURAL ENEMIES.—Numerous predaceous enemies of the mites developed in the orchard during July and August. Probably the most important predator observed was a small black coccinellid, identified as *Stethorus punctillum* Ws. by Dr. Curtis W. Sabrosky. The coccinellids were present in both the adult and larval stages. They were most abundant about mid-August, then began to subside.

A rather large, black species of thrips was abundant and active in both the adult and nymphal stages. The importance of this thrips as a predator is uncertain. The thrips seemed to be somewhat more resistant to sulphur than were the other predators observed.

Small cecidomyiid larvae were abundant during mid-August on the unsprayed trees. Very few were noticed on any of the sprayed plots. Small numbers of chrysopid larvae were noticed, and a very few predaceous mites were seen.

The greatest numbers of predators were noticed on the trees unsprayed after bloom almost as many were observed on the trees sprayed with lead arsenate only. It was very evident that the predators were an important factor in keeping down the red mite population on these two plots. Practically no predators were observed on the *TM-2*-lead arsenate plot until late August, and even then they were not numerous. They appeared to be slightly less numerous on the sulphur-lead arsenate-Aramite plot. Predators, especially thrips, were somewhat more abundant on the sulphur-lead arsenate plot, but here they were not sufficiently numerous to make much impression on the excessive population of red mites.

CONCLUSIONS.—Injury to the foliage resulted from the interaction of red mite activity and spray injury and was aggravated by high temperature. Of the materials used in the experiment, sulphur produced the most severe injury, but some injury from lead arsenate was apparent. Sulphur dust with lead arsenate concentrated in a mist spray, applied throughout the post-bloom period promoted severe infestation of European red mite on McIntosh apple trees. The addition of Aramite to the sulphur-lead arsenate applications, reduced the red mite population, but was not sufficient to prevent severe injury to the foliage. Some of the infestation probably came from mites drifting from the adjoining, heavily infested plot.

TM-2 with lead arsenate gave excellent control of the red mites, but was somewhat less effective than sulphur for scab control. *TM-2* probably destroyed most of the predaceous enemies as well as the mites.

Predaceous enemies were effective in holding the red mite population to a low level on the trees that were not treated after bloom, and on trees that were treated with lead arsenate only. Of course it is not recommended that a commercial grow-

er should not treat his trees after bloom, or that he should spray with lead arsenate only. The data presented here, however, emphasize the advisability of giving increased attention to the long-range side effects of the spray schedule.

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Control of the Two-Spotted Mite on Strawberries[1]

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The two-spotted mite is the most serious pest of strawberries in southeastern Virginia. This mite feeds by sucking the sap from the plant and causes a general loss of vigor, reduced yield and permanent stunting or death. Normally this pest occurs in damaging numbers only in late spring and during harvest but in unusually mild winters such as 1948–49 and 1949–50, the initial fall population continues to feed and multiply throughout the winter, resulting in an abnormally heavy infestation by early spring. Under optimum conditions dusting sulfur has given good results but has the following limitations; (1) comparative ineffectiveness at temperatures below 70° F; (2) danger of burning plants at temperatures above 80° F. in hot, dry weather; and (3) upsetting the soil reaction through repeated applications. During the past four years some of the newer insecticides were tested in an attempt to obtain a more satisfactory means of control. These results are presented here.

METHODS.—In evaluating the effectiveness of the various acaricides, it was found that more accurate results were obtained by making a direct count of all mites in a given area. This was due to the tendency of dead mites to be held in place for an extended period by the pubescent undersides of the strawberry leaves. The relative degree of control was obtained by selecting a given number of infested leaves, extracting a 0.3 square inch leaf plug from a heavily infested area and counting all living and dead mites by means of a binocular microscope. Only living mites were recorded in counts taken later than one week after treatment. Thirty samples were selected from each treatment replication in the 1947, '48 and '49 tests while 50 samples were taken in 1950.

Several methods of treatment were necessary as governed by the equipment available and location of the test area. Sprays were applied by a single nozzle knapsack-type hand sprayer operating at 30 to 50 lbs. pressure per square inch or by a power sprayer operating at 250 lbs. pressure with 4 nozzles directed on each bed. Dusts were applied by a rotary hand duster or by a motor driven tractor-drawn duster having the nozzles adjusted with three per bed and discharging under a 25-foot cloth trailer. Unless otherwise indicated, all treatments were replicated three times in randomized blocks. The dusts, in so far as possible, were prepared by adding the concentrate to pyrophyllite and mixing in a ribbon blade dust mixer for 20 minutes. All observations and treatments were made on the Blakemore variety of strawberries.

TESTS IN 1947 AND 1948—In field tests during April 1947 dinitro-sulfur (50–50) and 10 per cent azobenzene dust gave 95

[1] EASTERN BRANCH PROGRAM, 1950.

per cent and 93 per cent control, respectively, as compared to 83 per cent control with standard dusting sulfur. Hexaethyl tetraphosphate gave a high initial kill but failed to keep populations from building up quickly. Parathion at 0.25 per cent and a 1 per cent gamma isomer of benzene hexachloride dust were ineffective. Unfortunately the azobenzene dust caused such severe burning that it was eliminated from further consideration. The DN-sulfur combination produced some injury to the strawberry plants but did not appear to retard growth to any extent.

Extensive surveys throughout March of 1948 indicated the overwintering population of *Tetranychus bimaculatus* to be very low. Continued unfavorable conditions during the month of April held the mites at such a low level that it was difficult to find a satisfactory test area. Replicated 0.03 acre plots were treated with hand equipment April 16, 1948. All dusts were applied at approximately 40 lbs. per acre and the sprays at a 100 gallon per acre rate. The materials tested and results obtained are given in table 1.

Population counts taken April 20 show

Table 1.—Results of tests for control of the two-spotted spider mite, Norfolk, Virginia, April 16, 1948.

Material	Mite Population per 0.3 Sq. In. 4 Days After Treatment	
	No. Living Mites	Per Cent Reduction
Dusts:		
0.5% Parathion	2.7	96.0
1% Parathion	2.1	96.9
2% Parathion	1.4	97.9
8% bis (p-chlorophenoxy) methane[1]	7.2	89.4
DN[2]—Sulfur (50-50)	2.7	96.0
Sulfur	6.2	90.9
Sprays:[3]		
1 lb. bis (p-chlorophenoxy) methane	8.6	87.4
2 lbs. bis (p-chlorophenoxy) methane	7.6	88.8
4 lbs. bis (p-chlorophenoxy) methane	4.0	94.1
Check	68.0	—
L.S.D. 5%	2.3	

[1] *Neotran*, Dow Chemical Co.
[2] Contains 1.5 per cent dicyclohexylamine salt of dinitro-o-cyclohexylphenol. Dow Chemical Co.
[3] Expressed in terms of actual toxicant per 100 gallons.

that parathion and DN-sulfur dusts were significantly better than any of the other materials at standard dosages. Bis (p-chlorophenoxy) methane appeared promising at high concentrations but at lower rates failed to give any better performance than dusting sulfur. DN-sulfur caused severe injury to blossoms and leaves. Ripening berries treated with a 1 per cent parathion dust at the rate of 40 lbs. per acre had 0.2 parts per million parathion present when harvested 10 days later.

Additional experimentation after harvest indicated excellent *Tetranychus bimaculatus* control with sprays containing 1 to 2 lbs. of 15 per cent parathion wettable powder or 0.5 to 1 pint of 40 per cent tetraethyl pyrophosphate per 75 to 100 gallons of water per acre. Poor results were obtained with a 2 per cent tetraethyl pyrophosphate in pyrophyllite dust unless used within 24 hours after formulating.

In August large scale insecticidal and phytotoxicity tests were conducted on young berries using power equipment. Parathion at 2 lbs. of 25 per cent wettable powder and tetraethyl pyrophosphate (40 per cent) at 1 pint per 75 gallons of water per acre gave over 98 per cent mite control and failed to cause foliage injury despite extremely hot, dry weather ranging to 95° F. It is of interest to note that contrary to expectations as based on the results of previous tests, comparatively little mortality was observed in the tetraethyl pyrophosphate treatment during the first 24 hours. However, by the end of 48 hours an eventual kill of almost 99 per cent was recorded. Possibly the unusal weather conditions accounted for this lag in insecticidal action.

TESTS IN 1949.—Unseasonably warm weather in January and early February resulted in an abundance of two-spotted mites. All stages, including numerous freshly deposited eggs, were present by mid-February in such numbers that large scale insecticidal treatments were necessary to prevent serious crop damage. In view of the favorable late season results obtained with sprays the preceding summer, it was decided to make further studies along these lines.

On February 18 large scale cooperative spray tests were conducted near Norfolk, Va. Replicated 0.2 acre plots were treated with a power sprayer at the rate of 75 to 85 gallons of water per acre. The tem-

Table 2.—Results of spray tests for control of the two-spotted spider mite. Norfolk, Virginia. February 18, 1949.

Treatment[1]	Days After Treatment: 3 — Per Cent Mortality: Upper Leaves	3 — Per Cent Mortality: Lower Leaves	28 — Per Cent Reduction
1 lb. 15% Parathion wettable powder	65.0	32.7	0
2 lbs. 15% Parathion wettable powder	64.2	51.9	17.0
2 lbs. 15% Parathion wettable powder, .05 pint spreader[2]	71.0	66.7	21.5
1 pint 40% TEPP[3]	86.8	81.6	30
Check	0.7	1.2	—

[1] Amount per 100 gallons of water. 75–85 gallons applied per acre.
[2] *Aresket 240.* Monsanto Chemical Co.
[3] Westvaco Chlorine Products Corp.

perature at the time of application was 55° F. with a relative humidity of 60 per cent. The weather became somewhat warmer during the next two days, reaching a high of 60° F, on February 19, and 67° F, on February 20.

The results of these tests are presented in table 2. Tetraethyl pyrophosphate was the only material giving a rapid and fairly satisfactory initial kill. Few mites were found dead in the parathion plots during the first 48 hours but by 72 hours the degree of control had increased to the maximum. The surviving mites in the parathion plots were extremely jumpy and active as compared to a more or less quiescent condition in those from the other treatments. That there was little residual action is rather clearly indicated by the 28 day counts at which time none of the materials showed any worth while reduction in the number of mites. Separate records were kept on the upper and lower leaves as it was believed that low soil temperatures and poor coverage might result in a decreased kill in the case of the low lying leaves. In general, poorer control was obtained on the lower leaves although the difference was not quite as marked as expected. Repeated examinations indicated a soil surface temperature of 40 to 45° F. under the lower leaves. This temperature was fairly constant and, in view of the over-all flattened condition of the strawberry plants at this time of year, might explain the relatively poor results obtained.

Plots 150 feet long by 4 beds wide, were treated with a power duster March 29 at Norfolk. At the time of application the temperature was 71° F. and the relative humidity 79 per cent. A maximum temperature of 77° F. and 71° F. occurred March 29 and March 30, respectively. Materials tested and their results are given in table 3. All treatments gave a highly significant immediate action with 1 per cent parathion and 3 per cent crotonate being most effective. Relatively poor residual action was obtained with all material and several additional treatments were necessary in order to check mite development.

Tests in 1950.—Conditions favorable for *Tetranychus bimaculatus* development continued during the fall of 1949 and winter of 1950 and resulted in one of the most severe mite outbreaks on record. The average monthly temperature for January was 15.1 degrees F. above normal. as a result the strawberry plants did not enter a definite period of dormancy but maintained a semi-active growing condition throughout most of the winter. This

Table 3.—Efficiency of several acaracide dusts against the two-spotted spider mite. Norfolk, Virginia. March 29, 1949.

Material	Pounds per Acre	Days After Treatment: 3 — Per Cent Dead	9 — Mites per 0.3 Sq. In.	9 — Per Cent Reduction	30 — Per Cent Reduction
1% Parathion	35	88.2	2.7	94.5	25.4
1% 88-R[1]	33	72.8	9.2	81.3	35.7
Sulfur	40	66.6	7.5	84.8	39.5
3% dinitro capryl phenol crotonate[2]	37	89.7	3.1	93.7	40.6
Check		4.8	49.2	—	—
L.S.D. 5%			3.6		

[1] β chloroethyl (tert. butyl phenoxy) α methyl ethyl sulfite, Naugatuck Chem. Div., U. S. Rubber Co.
[2] *Arathane,* Rohm and Haas Co.

Table 4.—Effectiveness of winter treatments for two-spotted spider mite control, Oceana, Virginia, January 6, 1950.

	Amount per Acre Pounds or Gallons	Days After Treatment: 1 — Per Cent Mortality	4 — Mites per 0.3 Sq. In.	4 — Per Cent Reduction	30 — Per Cent Reduction
Dusts:					
Sulfur	50	39.0	7.1	74.6	40.3
1% Parathion	40	74.3	2.4	91.4	35.6
Dinitro[1]-Sulfur (50–50)	40	60.2	2.7	90.3	70.1
Sprays:[2]					
2 lbs. 15% Parathion wettable powder	75	53.1	4.1	85.3	20.6
1 lb. 15% Parathion wettable powder, 1 pint 20% TEPP[3]	85	65.2	3.3	88.2	18.5
2 pints 20% TEPP	80	88.1	1.5	94.6	0
1 quart herbicide, 6.5 gals. kerosene[4]	50	98.4	0.1	99.6	99.0
Check		1.1	27.9		
L.S.D. 5%			2.2		

[1] Contains 1.5 per cent dicyclohexylamine salt of dinitro-o-cyclohexylphenol. Dow Chemical Co.
[2] Amount toxicant per 100 gallons of water.
[3] Tetraethyl pyrophosphate. California Spray-Chemical Corp.
[4] 75 per cent dinitro ortho secondary amyl phenol (*Sinox General*), Standard Agr. Chem.

depletion of food reserves left the plants in a weakened condition which further accentuated the already severe mite damage.

A series of field scale tests was conducted at Oceana, Virginia, January 6, 1950. Conditions were typical of the general situation throughout the area and mites of all stages as well as freshly deposited eggs were present in large numbers and causing severe damage. The materials were applied to 0.3 acre plots at a temperature of 65° F. and relative humidity of 60 per cent. The maximum temperature for the two days following treatment was 76° F. and 75° F., respectively.

Table 5.—Results of spring treatments for two-spotted spider mite control. Norfolk, Virginia, 1950.

Treatment[1]	Mean No. Mites per 50 (0.3 Sq. In.) Leaf Samples, May 22 — Number	Per Cent Reduction	Yield in Quarts per 200 Ft. Row
1% Parathion	1802.9	40.3	43.0
1% Parathion, 96% Sulfur	356.4	88.2	46.8
1% Parathion, 2% C-854[2]	450.0	85.1	42.0
Sulfur	957.3	68.3	47.6
3% C-854[2]	779.2	74.2	43.0
2% EPN[3]	899.9	70.2	48.2
5% dinitro capryl phenol crotonate[4]	259.7	91.4	55.0
1 pint herbicide[5]	172.1	94.3	49.0
1 pint herbicide[5]+3.25 gal. kerosene	39.3	98.7	55.2
Check	3020.3	—	20.8
L.S.D. 5%	101.3		6.9

[1] The herbicide was applied March 20th at the rate of 1 pint per 50 gallons of water per acre. Dusts applied at approximately 35 lbs. per A. on April 5, 11 and 20.
[2] p-chlorophenyl p-chlorobenzenesulfonate, Dow Chemical Co.
[3] Ethyl p-nitrophenyl thionobenzenephosphonate, Dupont.
[4] *Karathane*, Rohm and Haas Co.
[5] 75 per cent dinitro ortho secondary amyl phenol (*Sinox general*), Standard Agr. Chem.

In addition to the standard insecticides and herbicide 75 per cent dinitro ortho secondary amyl phenol, was included. In weed control tests at Norfolk during the winter of 1948–49, Danielson (1949) observed that strawberry plantings treated with the herbicide were virtually free of mites the following spring whereas adjacent untreated areas were heavily infested. The toxic effect of the herbicide to the two-spotted mite was conclusively demonstrated by a series of field tests in which as little as 0.5 pint of toxicant per acre gave 99.4 per cent mortality 5 days after treatment (Hofmaster & Danielson 1950). As indicated in table 4 the 75 per cent dinitro ortho secondary amyl phenol combined immediate effectiveness with excellent long term protection. Dinitro-sulfur with a much lower mite reduction (70.1 per cent at the end of 30 days) was the only other material showing appreciable residual action.

Previous tests with parathion and tetraethyl pyrophosphate have shown a high initial mite kill but limited residual action. However, results from a small scale greenhouse experiment indicated that two additional applications of these materials at 4 to 5 day intervals practically eliminated

Table 6.—Results of post harvest treatments for two-spotted spider mite control. Norfolk, Virginia, June 6, 1950.

Treatment	Mean No. Mites per 50 (0.3 Sq. In.) Leaf Samples					
	Days After Treatment					
	3		6		15	
	Number	Per Cent Reduction	Number	Per Cent Reduction	Number	Per Cent Reduction
1% Parathion	41.1	96.7	38.6	96.4	240.2	67.2
1% Parathion, 96% Sulfur	17.2	98.6	9.2	99.1	21.3	97.1
1% Parathion, 2% C-854	45.3	96.3	17.6	98.3	21.8	97.0
Sulfur	122.4	90.1	69.1	93.5	68.4	90.6
3% C-854	346.2	72.1	120.2	88.7	60.3	91.8
5% dinitro capryl phenol crotonate	38.1	96.9	19.1	98.2	20.0	97.3
1% EPN	42.4	96.6	20.2	98.1	150.4	79.4
4% 4049[1]	73.5	94.1	32.4	96.9	221.1	69.8
Check	1240.1	—	1060.6	—	731.3	—
L.S.D. 5%	60.6		41.4		38.2	

[1] S—(1,2-Dicarbethoxyethyl) 0, 0-dimethyl dithiophosphate. American Cyanamid Co.

mites from sweet potatoes. Plots 100 feet long by 3 beds wide were established on March 20 to determine the effect of varying the type and number of treatments throughout the pre-harvest season. On this date the herbicide was applied as a spray, but a 0.25 inch rain prevented dusting. Weather conditions were unfavorable until April 5 at which time the remainder of the treatments were applied, only to be followed by a 0.48 inch rain and cool weather. Subsequent dustings on April 11 and 20 also received rain within 12 hours. Consequently, the only records taken were a population count at harvest and the yield. The usefulness of this experiment is limited by the abnormal weather conditions and the data are presented mainly to show the long term reduction in mite populations obtained with a single application of the herbicide (Table 5). All materials were surprisingly effective in reducing mite damage and gave yields more than double the untreated plots. The herbicide-kerosene combination and 5 per cent dinitro capryl phenol crotonate produced best quality berries and highest yields. It should be emphasized that the herbicide may only be applied during the winter dormant period of the strawberry plant and that its use in controlling the two-spotted mite would necessarily be restricted to that period (Danielson and Hofmaster 1950).

The results of post harvest insecticidal treatments are presented in table 6. Methods of application and experimental design were similar to the pre-harvest tests. Weather conditions were extremely hot and dry and daily temperatures above 90° F. were common. It will be noted that the mite population was declining during this experiment. This decline was in accordance with past observations from which it has been determined that the mites reach a peak at or near harvest, decreased to negligible proportions during the hot summer period and begin a gradual build up in the fall.

Observation of table 6 indicates that dinitro capryl phenyl crotonate, parathion-sulfur, and parathion-C-854 were outstanding for their rapidity of action and lasting protection. C-854 was slow in action but showed promising residual qualities. Combinations of parathion with sulfur and C-854 produced significantly better results than any of these materials alone. The phosphates again gave excellent initial control but limited protection later. The use of sulfur under such extreme weather conditions resulted in severe injury to the strawberry foilage; 5 per cent dinitro capryl phenyl crotonate caused some slight burning.

Summary and Conclusions.—A number of insecticides were tested from 1947 to 1950, inclusive, in an attempt to develop improved measures for two-spotted mite control on strawberries. The abnormal weather conditions during the past two winters together with the difficulty of thorough coverage early in the season somewhat complicated standard insec-

ticidal practices. It appears that low soil surface temperatures in winter or early spring greatly inhibit the action of such materials as parathion, sulfur, etc., although the air temperature may be fairly high at the time. This low temperature effect is further accentuated by the over-all flattened condition of the plants.

In general the organic phosphorous compounds were characterized by a high initial kill and limited residual action. At temperatures below 60° F., tetraethyl pyrophosphate was more effective than parathion, but the reverse was true at higher temperatures under the conditions of these investigations.

Dinitro capryl phenol crotonate, parathion-sulfur, and parathion C-854 were outstanding for their rapidity of action and lasting protection. Although C-854 was comparatively slow, it showed promising residual qualities. Combinations of parathion with sulfur and C-854 produced significantly better results than any of these materials alone. A dinitro-sulfur dust was effective but is limited to use in cool weather.

An herbicide, 75 per cent dinitro ortho ortho secondary amyl phenol gave best results. Applications during the dormant season at herbicidal concentrations effectively controlled the two-spotted mite and decreased or eliminated the need for later insecticidal treatments. The two-fold action of this material in controlling weeds and and the two-spotted mite simultaneously should prove of value to strawberry growers in southeastern Virginia.

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Data on the Natural Control of the Cyclamen Mite on Strawberries

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The cyclamen mite, *Tarsonemus pallidus* Banks causes serious injury to strawberries grown under field conditions in California. It has been estimated that losses due to the action of this pest in 1950 amounted to half-a-million dollars in this State alone. Some growers have suffered nearly complete loss of their crops. No suitable acaricidal or cultural means of combating this mite as a field problem has been developed. The technique of heat-trating nursery plants (Smith & Goldsmith 1936), although effective, is no longer practised since the present trouble does not arise from the use of infested planting stock.

The Division of Biological Control of the University of California has initiated a study aimed at utilization of predatory enemies in the alleviation of this problem. The first task in this effort has been to establish the degree of effectiveness of the common predators of the cyclamen mite. Many observers feel that the predator, *Iphidulus* sp.,[1] has frequently reduced infestation to a low level and maintained the control during the years immediately following an initial infestation. No quantitative data have been advanced in support of this view. This paper presents the results of population studies on this host-predator relationship. Lord (1949) published data on the action of a related species, *Iphidulus tiliae* (Oudeman) on the European red mite, *Metatetranychus ulmi* (Koch) on apples.

METHODS.—A means of evaluating the influence of this predator was suggested by the observation that in parathion-treated fields *Iphidulus* sp. immediately disappeared whereas the host, *Tarsonemus pallidus*, was little affected. This material was therefore used as a "check method" in paired-plot tests. *Four pairs*

[1] *Iphidulus* sp. as herein used has since been identified by Dr. H. H. J. Nesbitt as *Typhlodromus reticulatus* Oud.

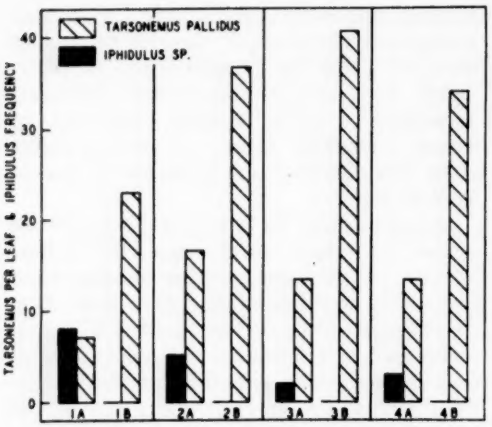

FIG. 1.—Density of *Tarsonemus pallidus* per leaflet and predator (*Iphidulus*) frequency on August 30, 1950 in predator and predator-free plots. Four pairs of plots were used. One plot of each pair had predators and the other was kept predator-free. The index of predator frequency is on the basis of the number of leaflets among 30 which had one or more *Iphidulus* sp. "A" plots are predator plots; "B" plots, predator-free.

of plots, each 30-plants in size, were used. One plot of each pair was dusted with parathion to produce a *predator-free* plot, and the alternate of the pair was left as the natural predator plot. Thus, direct comparisons are possible between predator-free plots and those where the predators were removed by use of parathion. Two of the pairs of plots, 1A, 1B, 2A and 2B, were located in the berries of one share-cropper on the north side of a road, while the other two pairs, plots 3A, 3B, 4A and 4B, were on the property of a second share-cropper, located just south of the same road. Although all plots were located on the property of the same general grower, the different handling, fertilization, *etc.* may be an explanation of part of the observed differences. The plots randomly assigned for treatment among each pair in the north location, (plots 1B and 2B, were treated with parathion on July 18. The plots so assigned for treatment among the south location, plots 3B and 4B, were treated two weeks later.

Between April 4 and April 20, the growers had treated the plantings with parathion for control of the two-spotted mite, *Tetranychus bimaculatus* Harvey. This had resulted in a prolonged reduction of the population of the predator, *Iphidulus* sp., while the subsequent numbers of *Tarsonemus pallidus*, already low, were not appreciably influenced. However, by the date the first treatments of this test were applied the predators had returned in small but noticeable numbers. Conditions were then suitable for a test involving a natural predator condition with a predator-free condition induced by use of the selective acaricide.

In any population study the use of a dependable system of partial census is imperative. The population estimates must be reproducible within reasonable confidence limits. In this study, this problem has been complicated by many factors. The estimates can be made only by removing a portion of the population. The most characteristic plant part for use as the sample item is the unopened, rolled leaf-shoot, and such leaves in the proper stage for sampling are always few in number and at certain seasonal periods are very scarce. The logical plant unit for sampling would otherwise be the individual strawberry plant, but since it was learned that only one leaflet unit can be taken with any hope of taking repetitious samples from the same plant at the required intervals, groups of plants had to be used as the plant unit of replication. Fortunately, it was found that the variation in mite numbers was low between the three leaflets of a leaf, and therefore greater economy in labor and less disturbance of the populations was experienced by taking only one of the three leaflets of a given leaf. It was also found that in a fairly late stage of an infestation the variation between leaflets was of about the same statistical order whether five leaflets were taken from five different but adjecent plants or whether one leaflet were taken from each of five different leaves of the same plant. This was encouraging, particularly since it developed that no more than one leaflet can be taken from the same plant at weekly intervals.

By taking three individual leaflets from each of 30 plants at a given position and by randomly selecting the count results from these leaflets in groups of variously-sized lots, it was found that 24 leaflets gave a dependable sample. However, this number was increased slightly and 30 leaflets were taken from each plot at each date.

The characteristic occurrence of *Iphidu-*

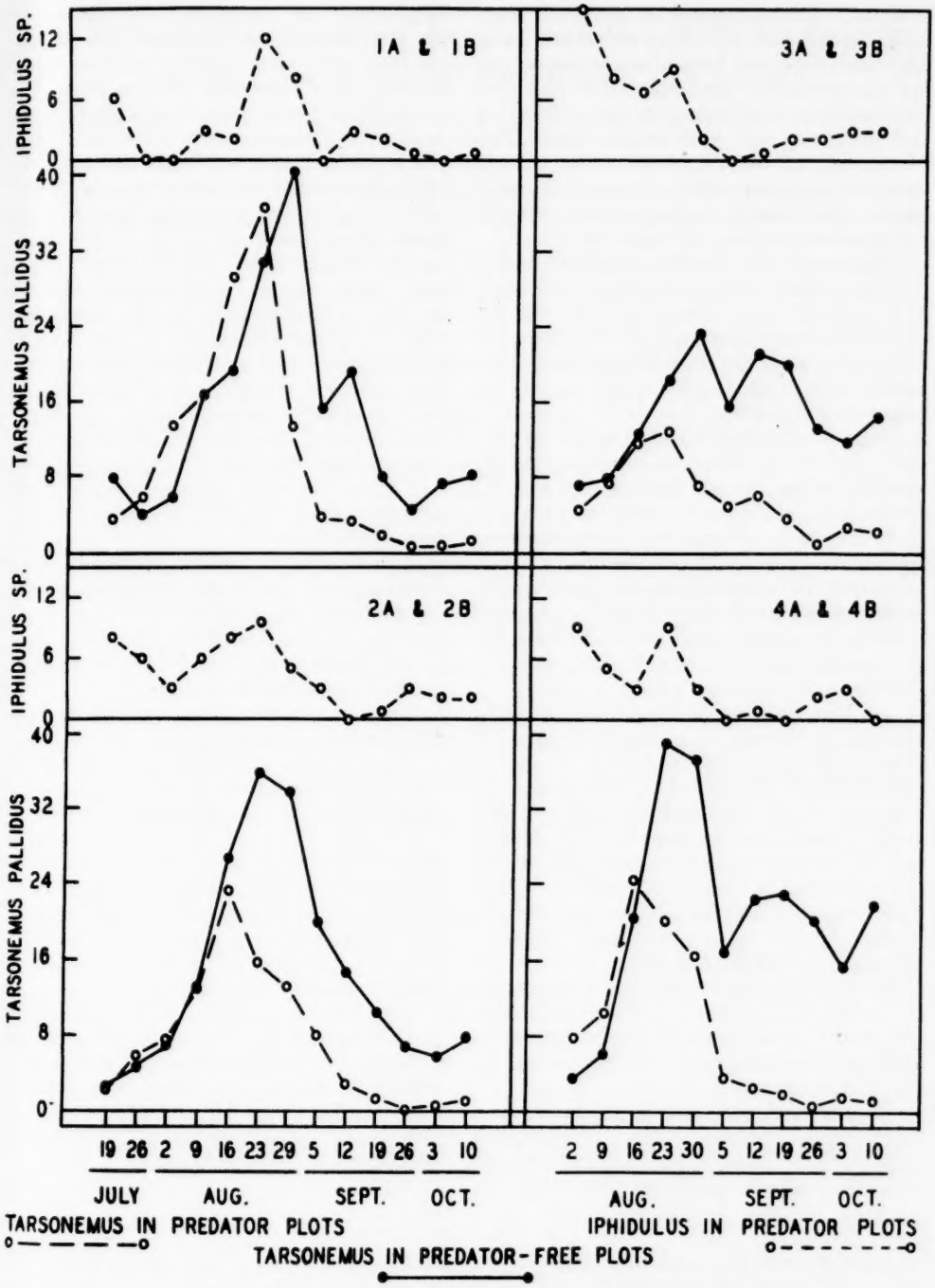

FIG. 2.—Changes in density of *Tarsonemus pallidus* in predator and predator-free plots, and associated predator (*Iphidulus*) frequency. Four pairs of plots were used. One plot of each pair had predators and the other was kept predator-free. The *T. pallidus* in the two plots of a respective pair of plots are plotted together, expressed on a per-leaflet basis. The index of predator frequency in the predator plots is on the basis of the number of leaflets among 30 which had one or more *Iphidulus* sp. The broken lines refer to the predator ("A") plots; the solid lines to the predator-free ("B") plots.

lus sp. is at a rate of one or two per leaflet. The occurrence of larger numbers on a few leaflets is not indicative of the action of the predators throughout the plot and this adds to discrepance in the correlation of predator and host populations. The frequency of occurrence of leaflets having predators (irrespective of predator numbers) was therefore taken as the measure of relative predator abundance.

RESULTS.—While the possibility of a "stimulation" of mite fecundity, directly or indirectly, by the parathion has not been disproved, the population patterns of the mites and their predators have been sufficiently logical to suggest a definite casual relationship.

The preliminary data from the predator *Iphidulus* plots, compared to the predator-free plots, indicate a definite influence by this predator upon the population level of its host, *Tarsonemus pallidus*. (Figure 1) presents in striking contrast the populations of both cyclamen mites and their predators at a single critical time, whereas figure 2 reveals the entire seasonal patterns of those populations.

As seen in figure 1, the cyclamen mites in the predator-free plots on August 30 had built up in each replicate to levels much higher than their occurrence at that time in the predator plots of the respective paired replicates. This decline of *Tarsonemus pallidus* under the action of *Iphidulus* sp. occurred at a time during the season (August 23 to August 30) when the host species was still in a phase of rapid increase (Fig. 2) in each of the four replicates which had had the predators destroyed. The use of the parathion kept the predators out of the predator-free plots throughout the period of the tests here reported.

Figure 2 shows that there was a close association between the presence of *Iphidulus* sp. and a continued depression of *Tarsonemus pallidus*. In order to emphasize the contrasts, the curves of the two comparable predator and predator-free plots were drawn together even though they represent results from distinct plots. There was a marked seasonal decline in *Tarsonemus pallidus* in all the plots (as well as in all fields observed) in early September, at which time a period of prolonged high temperatures and high desiccating power of the air was experienced. The fact that shortly afterward a secondary rise in *Tarsonemus pallidus* occurred in three of the four predator-free plots indicates that, subsequent to the effects from this period of unfavorable meterological conditions, there was a second slight reproductive surge. However, toward the end of September it became obvious that the seasonal peaks had passed and the seasonal decline had definitely set in, whether or not predators were present.

An attempt is being made to rear *Iphidulus* sp. in large numbers in the insectary. If these efforts prove successful, the evaluation of this predator and its utilization in the field can receive further necessary attention.

SUMMARY.—An acaricide check-method was used in evaluating the action of a laelaptid mite, *Iphidulus* sp., predatory upon the cyclamen mite, *Tarsonemus pallidus* Banks, on field strawberries in California. The predator and host population levels were taken at weekly intervals in four pairs of plots. One plot of each pair was dusted with parathion as a means of producing a predator-free plot, and the alternate of each pair was left as the natural predator plot.

The results, though not excluding the possibility of a chemical or residual "stimulative" influence, were sufficiently logical as to suggest strongly a definite control of its host by the predator. The depression of the mite was continued over considerable period of time.

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The Effect of Infestation by the Spider Mite *Septanychus tumidus* on Growth and Yield of Cotton[1]

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Injury to cotton by spider mites has been known for more than 40 years. Until recently infestations of cotton by spider mites have been sporadic and have most frequently involved comparatively small acreages. With the increasing use of synthetic organic insecticides for control of cotton pests, spider mite infestations have become more frequent and more widespread. Apparently the destruction of spider mite predators by these insecticides is responsible for the increasing importance of this cotton pest.

Although spider mites have been recognized as pests of cotton for many years there has been little work directed toward evaluation of the damage caused by them. McGregor (1934) cites an instance in which 20,000 acres of cotton in South Carolina suffered an estimated reduction of two fifths of a normal crop as a result of infestation by the two-spotted spider mite *Tetranychus bimaculatus* Harvey. In addition to *T. bimaculatus*, the species *Septanychus tumidus* (Banks)[2] and *S. texazona McGregor*[3] also occur on cotton in Louisiana.

Experimental Procedures and Results.—The effects of infestation by the spider mite *Septanychus tumidus* on growth and yield of cotton were studied in a randomized, replicated field plot experiment at Baton Rouge, Louisiana during 1950. The soil was prepared for planting in April, a 6–8–8 fertilizer applied at the rate of 500 pounds per acre, and the variety Deltapine 15 planted on May 4. When a stand had become established the plants were thinned to one plant per foot of row. Ordinary cultivation practices were followed during the remainder of the season. Plots were 8 rows wide and 70 feet long. Data were obtained from the two center rows of each plot.

Three applications of a concentrated spray at the rate of one pound of technical toxaphene per acre were applied to the entire experiment between May 10 and 22 for thrips control. In order to obtain control of other pests and to reduce the population of spider mite predators seven applications of a dust mixture containing 3 per cent gamma isomer BHC, 5 per cent DDT, and 10 per cent toxaphene were applied at the rate of 10 pounds per acre per application between June 16 and July 25. The experimental acaricide R-242[4] was applied as a spray at the rate of approximately 1.5 pounds of the technical material per acre July 7, July 12 and August 3 to prevent the establishment of spider mites in plots where no infestation was desired.

Infestations of the spider mite *Septanychus tumidus* were established by transferring infested cotton leaves from the greenhouse to the field plots. One infested leaf was placed on each plant June 5 on those plots where an infestation was desired. The population from these mites increased slowly and a second infested leaf was placed on the same plants June 20. Ten plants were selected in each plot to study development of the mite population through the season. The number of mites was counted by means of a linen tester on 1 square inch of the lower surface of 10 leaves on each plant, comprising a total of 100 square inches of leaf area per plot per count. A total of seven counts was made between June 16 and August 17. Results are given in table 1.

On each of three dates during the growing season 10 plants were selected at random from each plot, each cut off at the cotyledonary node and brought into the laboratory where the leaves were counted. The leaves were then removed from the plants and blueprinted by the sun print method described by Crowther (1934). Leaf area was determined by measuring the blueprint of each leaf with a planimeter according to the method used by Kreusler (1877). After the leaves were blueprinted they were dried in a laboratory

[1] This project was supported in part by a grant from Freeport Sulphur Co. Paper presented before meeting of Cotton States Branch, American Association of Economic Entomologists, Memphis, Tennessee, February 5, 1951.

[2] Mites were identified by E. W. Baker of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine.

[3] Personal communication from R. W. Harned.

[4] Stauffer Chemical Company's p-chlorophenyl phenyl sulfone.

Table 1.—Seasonal trend of mite population in experimental area. Baton Rouge, Louisiana. 1950.

Date Counted	Mites per Square Inch of Leaf Surface	
	Infested Plots	Uninfested Plots
June 16	2.82	0.00
June 23	5.23	0.00
June 28	5.35	0.08
July 5	10.26	0.33
July 13	18.80	0.37
Aug. 10	15.49	3.03
Aug. 17	16.82	2.57

Table 3.—The effect of spider mite infestation on dry matter produced by the plant. Baton Rouge, Louisiana. 1950.

Date	Ave. Dry Wt. of Leaves per Plant		Ave. Air-Dried Wt. of Plants	
	Infested Plots	Uninfested Plots	Infested Plots	Uninfested Plots
	Grams	*Grams*	*Grams*	*Grams*
July 14	18.7	23.8	54.5	68.4[2]
July 29	16.6	23.2[1]	71.9	96.4[1]
Aug. 12	10.8	20.0	99.5	134.9[1]
Average	15.4	22.4[1]	75.3	99.9[2]

[1] Significant at the 5% level.
[2] Significant at the 1% level.

oven at a temperature of 140 degrees F. for a period of 24 hours and weighed. The remainder of the plants, including the main stems, vegetative and fruiting branches, leaf petioles and fruit, were air dried in the greenhouse for a period of 2 months and weighed. Results are presented in tables 2 and 3.

Yield of seed cotton was obtained by picking the two center rows of each plot. Infested plots produced an average of 915 pounds of seed cotton per acre compared to 1663 pounds in the uninfested plots. This represented a reduction of 45 per cent in yield as a result of spider mite injury. The reduction in yield was significant at the one per cent level.

Reduction in yield of seed cotton as a result of injury from pests such as the spider mite may not represent the total loss since such injury may also reduce the value of the lint and seed. The nature of growth of cotton is such that there may be present on a plant at a given time fruit ranging from fully mature bolls to small flower buds. According to Brown (1938) from 45 to 65 days are required for the development of a boll. Therefore it may be possible to have some bolls developed while the plant is heavily infested by a pest and others developed during a time when the plant is relatively free of infestation. It has also been pointed out by Brown (1946) that seed and lint characters may vary as the fruiting season progresses. In order to minimize such variations the sample taken for study included only the bolls from the first node of the seventh fruiting branch on each of 40 plants per plot. Such a sample gave bolls which developed during a comparable time in the fruiting period.

The 40-boll sample from each plot was ginned with a laboratory gin designed to handle small samples. The following characters were studied on the resulting seed and lint: seed weight, seed viability, oil and ammonia content of the seed, lint percentage, lint weight, fiber maturity, fiber strength, and fiber length.

Seed weight is usually expressed as the seed index, which is the weight in grams of 100 representative seeds. The seeds from each 40-boll sample were counted and weighed. Oil and ammonia contents of representative samples of seed were de-

Table 2.—The effect of spider mite infestation on number of leaves and leaf area. Baton Rouge, Louisiana. 1950.

Date	Leaves per Plant		Ave. Leaf Area per Plant		Ave. Area per Leaf	
	Infested Plots	Uninfested Plots	Infested Plots	Uninfested Plots	Infested Plots	Uninfested Plots
	Number	*Number*	*Sq. Inches*	*Sq. Inches*	*Sq. Inches*	*Sq. Inches*
July 14	62	82[2]	638	912[1]	10.3	11.1
July 29	55	75[1]	558	832[1]	10.1	11.1
Aug. 12	40	64	351	656	8.8	10.2
Average	52.3	73.8[2]	515.5	800.2[1]	9.86	10.84

[1] Significant at the 5% level.
[2] Significant at the 1% level.

Table 4.—The effect of spider mite infestations on various seed characters. Baton Rouge, Louisiana. 1950.

	Seed Index	Oil Content	Ammonia Content	Quantity Index	Per Cent Viable Seeds
Infested plots	7.95	15.83	3.91[2]	90.44	61
Uninfested plots	9.83[1]	18.88	3.29	100.26	80

[1] Significant at 5% level.
[2] Significant at 1% level.

Table 5.—Effects of spider mite infestation on some lint characters of cotton, Baton Rouge, Louisiana. 1950.

	Lint Percentage	Lint Index	Lint Length Upper Half Mean	Pressley Index	Per Cent Immature Fibers
Infested plots	40.46	5.41	0.92	7.0	42.2
Uninfested plots	41.88	7.02[1]	1.03[2]	6.6[1]	17.4[2]

[1] Significant at 5% level.
[2] Significant at 1% level.

termined according to rules of the National Cottonseed Products Association.[1] Quantity index of the cottonseed was calculated according to rules for the 1945 crops (1947),[2] as follows: "For cottonseed that by analysis contains 16.5 per cent or more of oil, the quantity index shall equal 4 times the percentage of oil, plus 6 times the percentage of ammonia, plus 5. For cottonseed that by analysis contain less than 16.5 per cent of oil, the quantity index shall equal 6 times the percentage of oil, plus 6 times the percentage of ammonia, minus 28." These calculations showed a quantity index of 100.26 for cottonseed from the uninfested plots compared to 90.44 for that from infested plots. Representative samples of seed were germinated in a Mangelsdorf germinator which maintained the temperature at 91° F. Percentage viability was based on the number of seeds which germinated in 7 days. Results of these determinations are given in table 4.

Lint percentages of these samples were determined. According to Brown (1946) lint index, the weight of lint on 100 seeds measured in grams, is a better measure of lint production than is lint percentage because the latter is affected to a large extent by size and weight of seed. Lint length was measured with Hertel's fibrograph machine, and strength was determined by the Pressley strength tester.[3] Fiber maturity was studied by dyeing the fibers on the fifth seed, counted from the apical end of the lock, of each of 16 locks selected at random from each 40-boll sample. Fibers were dyed according to the differential dyeing method developed by Goldthwait, *et al.* (1947). When treated by this method mature fibers dye red and immature fibers dye green. After dyeing, cross sections were prepared,[4] mounted on a slide, and the number of red and green fibers counted according to the method given by Hunt (1947)[5] One hundred fibers from each of the 16 seeds were counted, giving a total of 1600 fibers examined per plot.

Results of the determinations of lint percentage, lint index, lint length, lint strength and per cent immature fibers are given in table 5.

DISCUSSION OF RESULTS.—From the data presented above it is apparent that infestations of cotton by spider mites may result in reduction in plant growth and yield and may affect the development of seed and lint. The effects of such an infestation are reflected in measurements of dry weight of plant, leaf area, and seed and fiber characters. Value of the cotton crop is influenced by seed and fiber properties so that the effect of an infestation by a pest such as the spider mite upon yield alone does not represent the total damage.

Spider mite injury is characterized by a reddening of the upper surface of the leaf. Depending upon the severity of infestation the reddened area may range in size from a small blotch to the entire upper surface of the leaf. Severe infestations may result in a complete defoliation of the affected plants. According to McGregor & McDonough (1917) feeding by the spider mite *Tetranychus bimaculatus* is accomplished by insertion of the mouth parts through the epidermis into the leaf tissue, the puncture being made from the underside of the leaf. These workers also state that cellular material in the immediate vicinity of the puncture is si-

[1] Cottonseed analyses by Francis Bonner, Feed and Fertilizer Laboratory, Louisiana State University.
[2] U.S.D.A., Production and Marketing Adm. Cotton Branch. 1947. Cottonseed Quality in the United States, Crops of 1944 and 1945.
[3] Length and strength of lint determined by M. T. Henderson, Agronomy Department, Louisiana State University.
[4] Using the Hardy Thin Cross-Section Device (1935).
[5] Hunt, O. J. 1947. Differential Dyeing and Cross-sectional studies as criteria for Estimating the Maturity of Cotton Fibers as Affected by Sampling, Variety, and Location. Unpublished Thesis, Louisiana State University.

phoned out, resulting in rupture of the parenchymal cells and shrinkage and distortion of the palisade cells. *Septanychus tumidus* appears to feed in a manner similar to that recorded for *T. bimaculatus*. This damage to parenchyma and palisade cells results in the destruction of chlorophyll, with consequent reduction in photosynthetic activity of affected leaves.

The amount of injury produced by spider mite infestation in this experiment was not so severe as that observed in many commercial plantings in Louisiana during 1950. Complete defoliation did not occur even in the most heavily infested plots whereas in some of the commercial plantings almost complete defoliation had occurred by the middle of August. Injury produced by the spider mite under the experimental conditions of this test is not considered in excess of that which occurs on large acreages.

As may be seen from a study of table 2 the number of leaves per plant was reduced an average of 29 per cent by spider mite injury. There was a gradual decrease in number of leaves per plant in the uninfested plots as well as the infested plots during the period in which leaf counts were made. Part of this decrease was no doubt the result of physiological shedding of senescent leaves. In addition to a decrease in the number of leaves per plant, leaves in the infested plots were almost 1 square inch per leaf smaller than those from uninfested plots. The decrease in leaf area together with the decrease in number of leaves resulted in an average reduction of 36 per cent in total leaf area per plant. This reduction in leaf area undoubtedly caused a decrease in photosynthetic efficiency. As would be expected with a decrease in leaf area there was a similiar decrease in air-dried weight of infested plants. This decrease amounted to 26 per cent.

The most serious effect resulting from spider mite infestation in this experiment was on the amount of seed cotton produced. The reduction in yield of seed cottou amounted to 45 per cent. Much of the top crop of bolls on the infested plants was shed. Many of the remaining bolls were small and immature.

Data obtained on the effects of spider mite infestation on seed and fiber properties were from bolls produced on the first node of the seventh fruiting branch and are not representative of the status of the total crop. With this limitation in mind it is evident from the data presented in tables 4 and 5 that spider mite infestations may reduce the value of lint and seed. A boll of cotton of the variety Deltapine 15 should produce 36 to 45 seeds depending upon whether it has four or five locks. A high percentage of bolls of this variety have four locks. Bolls from the uninfested plots in this test produced an average of 34 seeds per boll; those from infested plots produced an average of 24 seeds per boll. In addition to the loss in seed production represented by this decrease in number of seeds per boll, there was an additional loss because seeds from the infested plots weighed 19 per cent less than those from uninfested plots. These results indicate that infestation by the spider mite decreases the plant's ability to synthesize and translocate elaborated food to the developing seeds. Damage to cottonseed from the injury by this pest was further reflected by a decrease of 24 per cent in seed viability, and 16 per cent in oil content. On the other hand there was an increase of 16 per cent in ammonia content of seed from infested plots. This reduction in percentage of oil and increase in ammonia in cottonseed from the infested plots is in line with the high inverse correlation for these seed characters reported by Tharp, *et al.* (1949) in their study of the effect of fertilization and other environmental factors on yield and composition of cottonseed. Although the quantity index of seed from the infested plots was reduced by 10 points, this difference was not found to be significant.

According to Brown (1938) cotton fibers reach their full length during the first half of the maturation period, or about 25 days after blossom; secondary thickening of the fiber walls takes place principally during the second half of the maturation period. Measurements with Hertel's fibrograph machine showed that injury by the spider mite caused a decrease of 11 per cent in length of those fibers falling in the upper half mean. This decrease in fiber length indicates that injury from the spider mite infestation was in effect during the first half of the boll maturation period. An increase in percentage of immature fibers, as measured by the differential staining technique, from 17.4 in the uninfested plots to 42.2 in the infested plots indicates

that the injury was also in effect during the last half of the boll maturation period. The effect on fiber maturity was further reflected by differences in strength as measured by the Pressley strength tester. The Pressley index of samples from the infested plots was 7.0 as compared to 6.6 in the uninfested plots. The higher the value of this index, the greater the strength indicated for the sample.

It is known that environmental factors which set up physiological stress in the plant tend to cause an increase in fiber strength. For example, if the soil moisture supply during the period of secondary thickening of the fiber wall is below normal the strength of fibers will be above average for the variety. Removal of cell sap by the spider mite affected the normal physiological function of the plants causing an increase in fiber strength.

There was little difference in lint percentage of samples from infested and uninfested plots. This should have been expected in view of the relationship between size and weight of seed and lint percentage. Lint production determined on the basis of lint index showed a reduction of 23 per cent as a result of spider mite injury.

SUMMARY.—In a small field plot test conducted at Baton Rouge, Louisiana during 1950 injury to cotton resulting from infestation by the spider mite *Septanychus tumidus* (Banks) caused a 45 per cent reduction in the amount of seed cotton produced. This injury reduced vegetative growth as measured by the amount of dry matter produced, number of leaves per plant, and size of leaves.

In addition to these effects several characters of the seed and lint were adversely affected. On that portion of the crop represented by bolls developed at the first node of the seventh fruiting branch there were reductions in the average number of seeds per boll and in the weight, viability, and the oil content of the seeds. There was little effect on lint percentage as a result of mite infestation, but when the lint index was used as a criterion of lint production there was a sharp decrease. There was also a reduction in length and maturity of fibers which was attributable to spider mite injury.

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With the cooperation of the various members of the insecticide industry, the American Association of Economic Entomologists, Section on Insecticides has undertaken the sponsorship of insecticide reference standards. These standards are intended chiefly for bioassays of insecticides, however, they are also suitable for use as standards for chemical assays. It is felt that these standards will be useful in collaborative insecticide research studies. The following A.A.E.E. *Reference Standards* will be available on April 1, 1951:

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March 7, 1951
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Pea Aphid Control with Contact and Systemic Insecticidal Sprays[1]

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Prior to 1949, DDT had become the most commonly used insecticide for the control of the pea aphid, *Macrosiphum pisi* (Kltb.), by pea canners in the State of Wisconsin. While this insecticide does not constitute a residue hazard in canned peas, it does remain on the pea vines and pods, which are used as dairy cattle feed. Because of the likelihood of DDT appearing in the milk of cows fed on DDT-treated silage, the insecticide has lost much popularity as a pea aphid insecticide.

Dudley *et al.* (1948) have shown that low concentrations of parathion and tetraethyl pyrophosphate dust are equal to the commonly used 5 per cent DDT dust against the pea aphid. Anderson & Hofmaster (1948) reported relatively poor aphid control from hexaethyl tetraphosphate sprays applied by ground sprayer and aircraft. The need for more information concerning pea aphid control with sprays containing the newer synthetic insecticides prompted the authors to initiate such studies in 1949.

The work reported in this paper involved spraying with relatively low volumes per acre. This procedure was followed because of the current trend toward lower volumes with the use of weed sprayers. Some of the applications in 1950 were made at 5 gallons per acre which approaches the rate used by aircraft.

1949 Experiment.—The 1949 evaluation was conducted on an early field of Perfection peas.[2] The 19 treatments and a check were arranged in a randomized block design with four replicates. Individual plots were 7 feet wide and 100 feet long. Each plot was divided into thirds for post-treatment counts.

The sprays, which were all emulsions, were applied at the rate of fifteen gallons to the acre with a low volume weed sprayer mounted on a two-wheeled cart. Six fan-spray nozzles[3] spaced 12 inches apart were used in the boom, which was mounted at a height that would provide a continuous band of spray on the tops of the pea plants. All sprays were propelled by a gear pump at 35 pounds per square inch.

The single application of sprays was made on June 8, when the pea plants were about 2 days from blossoming. At intervals of 2, 7 (not shown in table 1), and 14 days after application, counts were made in the various plots to determine the aphid populations. These counts were obtained by shaking the aphids from 15 to 20 plants into a collecting pan placed between two rows. Since the number of plants varied in the different samples, the results were converted to aphids recovered per individual plant.

The various treatments employed and the results of the experiment are shown in table 1. The data in this table are divided into three groups for greater ease in making comparisons. In the first group, various dosages of parathion are compared with the standard treatment, one pound of DDT per acre. In the second group tetraethyl pyrophosphate (TEPP) and various combinations with tetraethyl pyrophosphate are compared with the standard DDT spray. In the final group, certain miscellaneous insecticides are compared with the standard.

In the first group, emulsified parathion at a much reduced dosage level proved to be as effective as DDT. Parathion showed a much higher initial kill than DDT but at the end of the two-week observation period aphid populations were approximately equal in the plots treated with parathion and DDT. Emulsifiable concentrates of parathion prepared with xylene and a methylated naphthalene[4] were equally toxic to the pea aphid. Sprays which provided 0.3 (1.2 pints 25 per cent) and 0.45 pound (1.8 pints 25 per cent of parathion to the acre caused slight injury to the foliage. The leaf injury was in the form of small browned areas.

In the second group of table 1, excellent pea aphid control was obtained by combinations of tetraethyl pyrophosphate with emulsifiable DDT. These combinations

[1] Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

[2] The authors wish to express their appreciation to the Oconomowoc Canning Company of Oconomowoc, Wisconsin, for permitting the experiments reported herein to be conducted on their fields.

[3] Monarch No. 32.

[4] *Velsicol AR 50G.*

gave high initial kill, due to the presence of tetraethyl pyrophosphate, while the DDT provided considerable residual toxicity. Such a spray would make a good pea aphid treatment except for the hazard of DDT on the pea silage. Combinations of tetraethyl pyrophosphate with emulsifiable rotenone proved to be quite effective, particularly at the highest dosage used, but such combinations did not have much residual toxicity. The rotenone in these combinations did not add much to the effectiveness of the tetraethyl pyrophosphate since tetraethyl pyrophosphate used alone gave about as good aphid control. Tetraethyl pyrophosphate alone showed high initial aphid control, but there was rapid reestablishment of the population. Plants sprayed with tetraethyl pyrophosphate or combinations containing this material developed a spotted condition on the foliage similar to that caused by the higher dosages of parathion.

In the third group shown in table 1, none of the insecticides at the dosages employed proved to be so effective as one pound of DDT to the acre. One quart of 25 per cent gamma benzene hexachloride per acre and the two dosages of 0,0-diethyl 0-p-nitrophenyl phosphate (oxygen analogue of parathion) gave good initial aphid kill, but after two weeks the aphid populations in these plots were higher than where DDT had been used. A comparison of 1 pint of 15 per cent 0,0-diethyl 0-p-nitrophenyl phosphate with a similar amount of parathion (1 pint 16 per cent) showed that these two materials were approximately equal in effectiveness against the pea aphid. The oxygen analogue caused foliage spotting at even lower dosages than did parathion. One quart of 25 per cent 2-nitro-1, 1-bis (p-chlorophenyl) propane and 1.5 pints of 4 per cent rotenone emulsion concentrate per acre were inadequate for pea aphid control.

1950 EXPERIMENTS.—During the second year of these studies, several new organic phosphate insecticides and a new chlorinated hydrocarbon were compared with DDT and parathion as contact sprays for pea aphid control. The 15 treatments and an untreated check were arranged in a balanced lattice design with five replicates.

The power spray equipment used in this test was the same as employed in 1949 except that the spray boom was extended to twelve feet and nozzles were interchanged to obtain the necessary variations in volume delivery. Three wettable powders were applied in fifteen gallons of spray to the acre at a pressure of 30 pounds per square inch with fan-spray nozzles.[1] Emulsions were applied at the rate of 5 gallons per acre with fan-spray nozzles at a pressure of 30 pounds per square inch.

Spray applications were begun on June 27 when the aphid population amounted to 15 aphids per sweep. The three wettable powder sprays were applied but rain prevented further application on June 27. The twelve emulsion sprays were applied on July 4 when the aphid population had risen to 33 aphids per sweep and plants were beginning to bloom. The seven-day interval which elapsed between June 27 and July 4 made it difficult to make comparisons between the wettable powders and emulsions; thus the results shown in table 2 include only the data from the use of insecticidal emulsions.

At intervals of 2, 7, and 14 days following the July 4 application of sprays, aphid populations were determined by taking the average of three sweeps of a 12-inch insect net in a randomly selected quarter-section of each plot. The average aphid populations and the corresponding population reductions for the first and last observation dates are given in table 2. Aphids per sweep were converted to logarithms for analysis because as the treatment means increased the within treatment variation increased proportionally (Snedecor 1946). Harvest samples were taken from each plot on July 28, but no significant difference in yield between various treatments was detected.

The results of the 1950 contact spray experiment shows that dosages of from 0.15 to 0.25 pound of parathion to the acre gave better than 90 per cent control of the pea aphid 2 days after treatment. Methyl homologue of parathion and parathion were equally effective against the aphid. A new organic phosphate, 0-(2-chloro-4-nitrophenyl) 0,0-dimethyl thiophosphate, also proved to be as effective as parathion against pea aphids.

Applications of 0.2 pound per acre of S-(1,2-dicarbethoxyethyl) 0,0-dimethyl di-

thiophosphate and diethoxy thiophosphoric acid ester of 7-hydroxy-4-methyl coumarin gave significantly poorer aphid control than an equivalent amount of parathion.

DDT was less effective than parathion even though it was used at a much higher rate per acre. One pound of 1,1-bis (p-ethylphenyl)-2,2-dichloroethane per acre was just as effective as an equal amount of DDT in-so-far as initial kill was concerned but it was much inferior to DDT from the standpoint of residual toxicity.

SYSTEMIC TESTS.—The report by Ripper *et al.* (1950) on the use of octamethyl pyrophosphoramide as a systemic insecticide against aphids on peas created an entirely new approach to the control of such insects. Two tests were conducted against the pea aphid with systemic insecticides during 1950 to determine the duration of effectiveness of such materials under actual field conditions.

The first of these tests was a comparison of pre-planting with foliage applications of octamethyl pyrophosphoramide at three dosage levels and at two different volumes of spray to the acre. The preplanting application involved spraying of the systemic insecticide on the soil May 19, followed by two discings prior to seeding with Perfection peas on May 22. The foliage sprays were applied to separate plots on June 21, at which time the peas had reached the eight node stage and the population was 4.3 aphids per sweep.

The spray cart mentioned previously was used to apply both the pre-planting and foliage sprays. The spray boom was provided with a separate set of nozzles for the 10 gallon and 50 gallon applications. With both rates of application, a pressure of 30 pounds per square inch was employed.

The 12 treatments and untreated check were arranged in four replicates of a ran-

Table 1.—Control of the pea aphid with various insecticidal emulsions sprayed at 15 gallons per acre. Madison, Wisconsin—1949.

Dosage per Acre 6/8	Aphids per Plant		Per Cent Reduction		Foliage Injury
	6/10	6/22	6/10	6/22	
Group 1:					
1.2 pts. 25% parathion[1]	0.3	2.7	93.0	66.7	slight
1.2 pts. 25% parathion[2]	0.5	2.8	88.6	65.4	slight
2 qts. 25% DDT	1.5	2.8	64.2	65.4	none
1.8 pts. 25% parathion[2]	0.2	3.4	94.0	58.0	slight
1.8 pts. 25% parathion[1]	0.2	3.6	95.9	55.6	slight
1 pt. 16% parathion[1]	0.7	4.2	82.1	48.1	none
Group 2:					
2 qts. 25% DDT+1 qt. 20% TEPP	0.3	2.0	93.0	75.3	slight
2 qts. 25% DDT	1.5	2.8	64.2	65.4	none
1 qt. (22.7% DDT+2.5% TEPP)	0.5	3.0	88.1	63.0	slight
2 qts. (22.7% DDT+2.5% TEPP)	0.4	3.1	90.1	61.7	slight
1.5 pts. 4% rotenone+1 qt. 20% TEPP	0.5	4.0	87.9	50.6	none
1 qt. 20% TEPP	0.6	5.0	86.4	38.3	slight
1 qt. (3.16% rotenone+4.74% TEPP)	1.2	5.5	71.0	32.1	slight
1 pt. (3.16% rotenone+4.74% TEPP)	3.4	7.3	17.9	9.9	slight
1 pt. 20% TEPP	1.2	7.6	71.0	6.2	slight
Group 3:					
2 qts. 25% DDT	1.5	2.8	64.2	65.4	none
1 qt. 25% gamma benzene hexachloride	0.7	4.4	82.6	45.7	none
1 pt. 15% 0,0-diethyl 0-p-nitrophenyl phosphate	1.2	4.8	69.7	40.7	slight
0.5 pt. 15% 0,0-diethyl 0-p-nitrophenyl phosphate	0.5	5.0	87.2	38.3	slight
1 qt. 25% 2-nitro-1, 1-bis (p-chlorophenyl) propane	3.7	10.9	10.0	0.0	none
1.5 pts. 4% rotenone	2.7	8.2	33.7	0.0	none
Untreated	4.1	8.1			
L.S.D. 5%	1.6	4.9			
L.S.D. 1%	2.1	6.5			

[1] Xylene solvent used in emulsion concentrate. [2] Velsicol 50G solvent used in emulsion concentrate.

domized complete block design. The 12 by 50 foot plots were divided into three equal sections so that results could be obtained from different portions of each plot during subsequent observation. This split-plot factorial experiment provided greater precision for the comparison of treatments. Results were obtained by taking three sweeps per plot on each date of observation with a 12-inch insect net. The first observation was made July 2, which was 44 days after sprays had been applied to the soil and 11 days after foliage applications. Subsequent data were obtained on July 11 and July 21. The July 21 observation was 7 days prior to harvest. Results of this experiment are shown in table 3.

Application of octamethyl pyrophosphoramide to the foliage was found to give significantly better pea aphid control than pre-seeding application. However, where 4 pounds of toxicant were used in 50 gallons per acre as a soil treatment, aphid control was comparable with 1 and 4 pound applications to foliage. The systemic insecticide applied in 50 gallons per acre indicated a slight advantage over a 10 gallon rate, but the differences were not great enough to be significant.

With all methods of application, a quarter pound of octamethyl pyrophosphoramide per acre was found to be less effective than 1 pound per acre. One pound per acre gave as good aphid control as 4 pounds per acre, when applied as a foliage spray. As a pre-seeding soil application, the 1 pound per acre dosage was somewhat less effective than the higher dosage but in most cases the differences were not significant.

Peas were harvested and canned on July 28 from plots treated with 4 pounds of octamethyl pyrophosphoramide per acre applied as a foliage spray and to the soil before planting. Seventy days elapsed between soil treatment and harvest while there were 37 days from the

Table 2.—Control of the pea aphid with insecticidal emulsions at 5 gallons per acre. Madison, Wisconsin—1950.

	Aphids per Sweep				Per Cent Reduction	
	July 6		July 18			
Dosage Technical per Acre 7/4	Log	Antilog[1]	Adj. Log[2]	Antilog	July 6	July 18
Group 1:						
0.25 lb. parathion	0.52	2.3	1.35	22	96.2	87.4
0.04 lb. parathion+0.16 lb. methyl homologue of parathion[3,4]	0.77	4.9	1.38	24	91.9	86.2
0.20 lb. methyl homologue of parathion	0.95	7.9	1.43	27	87.0	84.5
0.15 lb. parathion	0.60	3.0	1.49	31	95.1	82.2
0.20 lb. parathion	0.77	4.9	1.58	38	91.9	78.2
0.02 lb. parathion+0.18 lb. methyl homologue of parathion[4]	0.78	5.0	1.64	44	91.8	74.7
Group 2:						
0.2 lb. 0-(2-chloro-4-nitrophenyl)-0,0-dimethyl thiophosphate	0.68	3.8	1.41	26	93.7	85.1
0.03 lb. rotenone+0.07 lb. methyl homologue of parathion	1.05	10.2	1.66	46	83.2	73.6
0.2 lb. S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate	1.26	17.2	1.90	79	71.7	54.6
1.0 lb. DDT	1.40	24.1	1.92	83	60.3	52.3
1.0 lb. 1,1-bis(p-ethylphenyl)-2,2-dichloroethane	1.43	25.9	2.14	138	57.3	20.7
0.2 lb. diethoxy thiophosphoric acid ester of 7-hydroxy-4-methyl coumarin	1.62	40.7	2.29	195	32.9	0.0
Untreated	1.79	60.7	2.24	174		
L.S.D. 5%	0.18		0.15			
L.S.D. 1%	0.24		0.20			

[1] One was subtracted from the antilog because the analysis was performed on log (aphids per sweep+1).
[2] The precision factor relative to randomized complete blocks was 166 per cent. This necessitated the use of adjusted values.
[3] Derived from Metacide. [4] Polyethylene glycol ether solvent and emulsifier employed.

Table 3.—Pea aphid control from pre-planting and foliage applications of octamethyl pyrophosphoramide. Madison, Wisconsin—1950.

Octamethyl Pyrophosphoramide Lbs. per Acre	Gallons Spray per Acre	Aphids per Sweep			Per Cent Reduction		
		7/2	7/10	7/21	7/2	7/10	7/21
Treatments applied to soil May 19, three days prior to seeding							
0.25	10	18.9	37.5	85.8	31.3	12.0	19.4
1.00	10	8.0	28.4	36.0	70.9	33.3	66.2
4.00	10	5.8	21.8	41.5	78.9	48.8	61.0
0.25	50	16.2	34.6	59.0	41.1	18.8	44.6
1.00	50	6.7	21.2	44.5	75.6	50.2	58.2
4.00	50	2.6	3.6	18.2	90.5	91.5	82.9
Treatments applied to foliage June 21—aphid population 4.3/sweep							
0.25	10	7.6	21.2	73.0	72.4	50.2	31.4
1.00	10	1.3	4.4	20.8	95.3	89.7	80.5
4.00	10	2.2	4.8	17.0	92.0	88.7	84.0
0.25	50	9.1	33.2	58.2	66.9	22.1	45.4
1.00	50	1.6	6.2	17.0	94.2	85.4	84.0
4.00	50	1.2	2.0	8.0	95.6	95.3	92.5
Untreated		27.5	42.6	106.5			
L.S.D. 5%		6.1	14.4	32.9			
L.S.D. 1%		8.2	19.4	44.2			

time of foliage application until harvest. Chemical analyses[1] of the canned peas showed less than 0.1 p.p.m. of insecticide to be present. At the time of pea harvest a sample of vines (pods and foliage) was gathered from plots treated with 4 pounds of octamethyl pyrophosphoramide per acre applied to the foliage. After being dried, the vines were found to contain 2.0 p.p.m. of the insecticide. On a green weight basis, the residue amounted to 0.3 p.p.m.

A small plot experiment was conducted with three systemic organic phosphate insecticides as foliage sprays against the pea aphid. These materials included octamethyl pyrophosphoramide, a trialkyl seleno phosphate,[1,2] and a trialkyl thiophosphate.[1,2] The toxicants were applied at the rate of 4 ounces in 22 gallons of water to the acre with a knapsack sprayer on June 22. The three treatments were randomized in a latin square design with individual plots measuring 12 by 36 feet.

On July 8 and July 21, the aphid populations were determined in the respective plots by sweeping with an insect net. The findings are given in table 4. Both trialkyl seleno phosphate and trialkyl thiophosphate proved to be more effective than octamethyl pyrophosphoramide on July 8, which was 16 days after application. Thirteen days later, however, the aphid populations were approximately equal with all treatments.

At harvest, July 28, peas were gathered and shelled from the various plots in this experiment. The peas were canned by the Dairy Industry Department of the University of Wisconsin within a few minutes after shelling. Analysis of the canned peas showed that a small quantity of systemic insecticide was present in peas treated with 0.25 pound of trialkyl seleno phosphate and trialkyl thiophosphate per acre, but none in peas treated with octamethyl pyrophosphoramide. Dried pea vines from plots treated 36 days before harvest with a quarter pound of trialkyl thiophosphate per acre contained 1 p.p.m. of the systemic insecticide.

Summary.—Spray experiments were conducted in 1949 and 1950 to find a toxicant that could replace emulsifiable DDT for pea aphid control, since this insecticide constituted a milk contamination hazard when present on pea silage fed to dairy cattle.

Treatments were applied at the rate of 15 gallons per acre in 1949 and at 5 or

[1] Geary Corp. E-20/58. All peas treated with this selenium insecticide were destroyed before field was harvested by canning company.

[2] Geary Corp. E-1059.

Table 4.—**Pea aphid populations and insecticidal residues in canned peas following foliage application of three systemic insecticides for pea aphid control. Madison, Wisconsin—1950.**

Dosage Technical per Acre 6/22	Aphids per Sweep 7/8	Aphids per Sweep 7/21	P.p.m. of Systemic Insecticides in Canned Peas[1]
0.25 lb. trialkyl seleno phosphate	8.3	36.3	0.25
0.25 lb. trialkyl thiophosphate	8.6	39.3	0.15
0.25 lb. octamethyl pyrophosphoramide	18.1	41.0	Nil
L.S.D. 5%	8.5	n.s.	
L.S.D. 1%	12.8		

[1] Peas harvested July 29. Octamethyl pyrophosphoramide determination by chemical assay (Dow Chemical Co.). Biological assay employed for other analyses (Geary Chemical Corp.).

15 gallons to the acre in 1950 by means of a low pressure weed sprayer.

Parathion at 0.2 pound per acre was found to be highly effective against the pea aphid. This insecticide gave very high initial kill and this fact was responsible for relatively low aphid populations 2 weeks following application. The oxygen analogue of parathion, was no more effective than parathion. The methyl homologue of parathion and combinations of this chemical with parathion were found to be as effective as parathion used alone. A new phosphate insecticide, 0-(2-chloro-4-nitrophenyl) 0,0-dimethyl thiophosphate, proved to be comparable with parathion.

A 20-per cent tetraethyl pyrophosphate emulsifiable concentrate applied at one quart to the acre demonstrated good initial kill but very poor control at the end of 2 weeks. Combinations of tetraethyl pyrophosphate with DDT showed greater residual toxicity because of the presence of DDT. The gamma isomer of benzene hexachloride caused an immediate aphid kill but the reestablishment followed shortly thereafter.

Insecticidal emulsion sprays found to be unsatisfactory against pea aphids at the dosages employed included the following: rotenone, 2-nitro-1,1-bis (p-chlorophenyl) propane, S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate, diethoxy thiophosphoric acid ester of 7-hydroxy-4-methyl coumarin, and 1,1-bis (p-ethylphenyl) dichloroethane.

Preliminary trials with a systemic insecticide, octamethyl pyrophosphoramide, showed that 1 pound per acre of the toxicant was needed to obtain satisfactory aphid control when applied to the pea foliage while 4 pounds per acre were required when applied to the soil prior to seeding. There were indications that the systemic insecticide was more effective when applied in 50 gallons per acre than when applied in only 10 gallons per acre but the advantage shown by the higher volume of spray was not significant.

Less than 0.1 p.p.m. of octamethyl pyrophosphoramide was detected in canned peas taken from plots treated with four pounds of the toxicant per acre applied as a foliage spray and as a preseeding soil treatment. Where the foliage spray had been used, there were 2.0 p.p.m. of toxicant in the dried pea vines.

In a second experiment involving foliage sprays with systemic insecticides, one-fourth pound of trialkyl seleno phosphate or trialkyl thiophosphate per acre gave significantly better aphid control than a like amount of octamethyl pyrophosphoramide 16 days after application. No real difference existed, however, among the three materials 29 days following treatment.

Canned peas from the plots treated with the three systemic insecticides, showed no octamethyl pyrophosphoramide but 0.25 and 0.15 p.p.m. of trialkyl seleno phosphate and trialkyl thiophosphate, respectively, were found. Dried pea vines, taken at harvest time, had 1 p.p.m. of trialkyl thiophosphate.

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Stalk Breakage of Dent Corn Infested with the August Generation of the European Corn Borer[1,2]

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Broken tassels and stalks of corn are indications of an infestation by the European corn borer, *Pyrausta nubilalis* (Hbn.). The larvae tunnel in the stalks and ear shanks, thus weakening them to the extent that they break and interfere with the proper development of the ears and their harvest by a mechanical corn picker.

The effect of the single-generation strain of the corn borer on dent corn was studied by Ficht[4] in 16 fields within a block 1 mile square in Kent County, Ontario, during a severe outbreak in 1925. The borer populations varied with planting dates, decreasing from 36.6 mature borers in a field planted on May 12 to 1.8 borers per plant in a field planted on June 20. Over this range of planting dates the breakage of stalks below the ears decreased from 33.5 to 1.1 per cent, and the breakage above the ears decreased from 71.9 to 11.8 per cent. All the shanks were infested in the fields where the borers averaged more than 22 per plant, 45 per cent were infested in 6 fields averaging 12.5 borers per plant, 35 per cent in 3 fields averaging 5.8 borers, and 2 per cent in the field with 1.8 per plant.

The effect of the August generation of the multiple-generation strain was studied in 1944 in plots of various corn hybrids in a late May planting near Lafayette, Indiana. These plots contained very little infestation from the June flight of moths, and the infestation by the August moths had been augmented by laboratory-produced eggs placed on the plants by hand. The purpose of this paper is to present differences among these hybrids in stalk breakage below the ear and in infestation in the ear shank due to second-generation borers. The loss in yield due to stalk breakage as compared with that due to the reduction in size of ear is also discussed.

Infestation With Eggs and Location of Borers in the Plants.—Sixteen single cross hybrids were planted in plots of six 6-hill rows with sevenfold replication. The hills, each of which contained three plants, were 40 inches apart. Rows 1 and 2 were subjected to natural infestation only, rows 3 and 4 had three egg masses placed on each plant in addition to the natural infestation, and rows 5 and 6 received six egg masses per plant. The egg masses were obtained in quantity from moths reared in the laboratory. Small disks of waxed paper each bearing an egg mass were pinned on the plants just before the eggs hatched. The eggs hatched between August 4 and August 11, or from 1 to 8 days after most of the hybrids began to show silks, and near the peak of natural infestation on August 10.

Beginning the second week in September plant samples were dissected to determine the number and size of borers surviving and their locations in the plants. One plant was taken from rows 1, 3, and 5 from each plot of each hybrid. Three days later the second set of samples was taken from rows 2, 4, and 6. This alternation was repeated until the eighth set of samples was dissected on October 5.

An analysis of the data showed that the three persons dissecting the plants were about equally efficient in finding and recording the borers, and that the size and location of the borers in the plants receiving the additional egg masses by hand were closely similar to those of the borers in the naturally infested plants.

With the advance in the season a pronounced change in numbers of borers and their locations in the plants occurred. These changes are shown in table 1. Locations outside the stalks lost 4.5 borers, those inside the stalks above the ears lost 0.8 borer, and those inside below the ears gained 1.3 borers per plant between September 9 and October 5. There was a net loss of 4.0 borers, or 40.4 per cent of the borers present on September 9. Most of these apparently disappeared from the plants without entering the stalks.

[1] Journal Paper No. 362 of the Purdue University Agricultural Experiment Station.

[2] Presented at the meeting of the American Association of Economic Entomologists in New York City, Dec. 13–16, 1948.

[3] *Formerly of U.S.D.A., Agr. Res. Adm. Bureau of Plant Industry, Soil, and Agricultural Engineering.*

[4] Data taken from a report by G. A. Ficht, deceased, were made available to the authors by H. G. Crawford, Dominion Entomologist, and H. L. Seamans, Chief, Field Crop Insect Investigations, Science Service, Canadian Department of Agriculture.

Table 1.—Locations of borers on four dates in the plants receiving additional eggs, Lafayette, Ind., 1944.

Location	Number of Borers per Plant			
	Sept. 9	Sept. 21	Sept. 28	Oct. 5
Outside Stalks:				
Ear	2.8	0.9	0.5	0.4
Ear shank	0.7	0.4	0.2	0.1
Behind leaf sheaths	2.1	1.4	1.0	0.6
Total	5.6	2.7	1.7	1.1
Inside Stalks:				
Above ears	2.7	2.3	2.1	1.9
Below ears	1.6	2.2	2.6	2.9
Total	4.3	4.5	4.7	4.8
Grand total	9.9	7.2	6.4	5.9

Table 2.—Percentage of single-cross hybrid plants infested with borers in the ear shanks between September 9 and 18, Lafayette, Ind., 1944.

Inbred Lines	Inbred Lines			
	Ind. P8	Ill. R4	Ind. WF9	Ill. A
Kan. K230	2.1	6.4	8.6	
Ia. L317	3.7	6.2	7.4	
Ind. WF9	6.5	11.8	—	10.7
CI. 187-2		8.7	10.9	10.8
Ill. R4	2.4			
Ia. L304A	3.1			

About 7 per cent of the borers were in the ear shanks of all the hybrids on September 9, but consistent differences were observed among the hybrids as shown in table 2. It appears that lines P8, K230, L317, and L304A may contribute resistance to shank infestation, and lines WF9, 187-2 and A might be susceptible, with line R4 contributing somewhat less susceptibility than WF9.

These tentative ratings of resistance to shank infestation given to the inbreds when in single-cross combination under the August infestation of borers agree closely with those given by Patch and Everly (1945) to the same inbred lines on the basis of the survival of the June infestation of borers in the entire plant.

The number of ears that dropped to the ground prior to harvest was negligible. In the single crosses involving inbreds P8, R4, and WF9 on the common parents K230 and L317, only 0.3, 0.9, and 0.7 per cent of the ears dropped to the ground.

STALK BREAKAGE BELOW AND ABOVE THE EAR.—During the period October 9 to 13 all plants were examined for stalk breakage from any cause. No storms occurred between those dates. Breaks just below the tassel were disregarded, but other breaks above the ear were recorded. Since the total number of plants available after the taking of samples to determine borer populations varied from 84 to 96, according to the hybrid, percentages were used in the analysis of the data on stalk breakage.

The linear regression (B) of the percentage of plants broken (Y) on the number of borers per plant (X) was calculated for each hybrid by using the six pairs of data available from rows 1 to 6. Since the borers actually within the stalks would be the ones most likely to cause breakage, the numbers within the stalk below the ear when they were at a maximum on October 5 were used in studying breakage below the ear. Since the samples of plants dissected on October 5 were too small to give a good estimate of the number of borers per plant below the ears on that date in each row of each hybrid, estimates were made by calculating linear regression based on the results of the dissections made on that and previous dates.

In a similar manner the linear regression of the percentage of plants broken above the ear on number of borers per plant above the ear on September 9 was calculated for each hybrid. The borers were at a maximum in that location on that date.

There were about as many borers inside the stalks above the ears on September 9 as there were below the ears on October 5. On the basis of B, the percentage of plants broken below the ear of all the hybrids increased from 9.7 to 25.0 as the borers below the ear increased from 0.5 per plant in row 1 to 3.3 per plant in row 6. On the same basis the percentage of plants broken above the ear increased from 44.6 to 83.5.

By using the linear regressions of Y on X, the percentages of broken plants in the different hybrids were estimated for 0.5 borer per plant and for each additional borer per plant (Table 3). It is apparent that the same number of borers per plant caused much more breakage in some of the hybrids than in others, that there was much more breakage above than below the ears in all the hybrids, and that there was no definite correlation between breakage above and breakage below the ears.

Table 3.—Percentage of stalks of dent corn hybrids broken below and above the ear in relation to the number of European corn borers tunneling in the stalks, Lafayette, Ind., 1944.

Single-Cross Hybrid	For 0.5 Borer per Plant Below the Ear		Increase with Each Additional Borer per Plant (B)	
	Below the Ear	Above the Ear	Below the Ear	Above the Ear
Ind. WF9×CI. 187-2	0.7	31.8	0.9± .33	11.8±2.26
Ind. WF9×Ill. A	2.2	53.4	3.1± .95	12.0±2.93
Ind. WF9×P8	3.0	37.6	2.0± .95	15.3±3.03
Ind. WF9×Kan. K230	3.1	55.2	3.4±1.10	26.1±5.02
Ill. A×CI. 187-2	5.0	23.9	1.6± .72	14.5±2.21
Ind. TR×Ill. Hy	5.8	46.2	4.4±1.62	10.9±2.35
CI. 187-2×Ill. R4	6.1	67.8	5.5±2.94	8.7±2.82
Ind. P8×Kan. K230	6.6	16.4	5.1±2.14	20.6±3.01
Ind. P8×Ill. R4	7.1	72.0	7.1±2.68	9.2±2.59
Ind. WF9×Ill. R4	8.4	76.3	0.8±1.06	6.3±2.32
Ind. WF9×Ia. L317	10.5	49.3	6.7±2.03	11.1±2.30
Ia. PR×Ind. 38-11	12.9	31.6	7.2±2.31	22.6±3.83
Ind. P8×Ia. L304A	15.3	37.1	7.1±1.73	31.7±3.92
Ind. P8×Ia. L317	19.7	31.1	11.9±2.61	13.2±2.13
Ill. R4×Kan. K230	20.8	68.3	6.4±2.99	13.0±2.72
Iil. R4×Ia. L317	36.4	42.5	8.8±2.84	12.1±3.27
Mean	10.2	46.3	5.13±0.500	14.94±0.754

In table 3 the hybrids are listed in the order of increasing percentage of breaks at 0.5 borer per plant in the stalks below the ear. Excluding data from hybrid WF9 × R4, whose value of *B* is decidedly unreliable because of its large standard error, five groups of three hybrids each may be made. The percentage of plants broken is plotted in figure 1 against the number of borers in rows 1 to 6 for each of the five groups and regression lines are fitted to the plotted data. The regression coefficients, *B*, and the partition of sums of squares of *Y* are given in table 4. Figure 1 and table 4 show that, when 2.2, 4.4, 6.8, 13, and 25 per cent of the plants were broken at 0.5 borer per plant below the ear, each additional borer per plant below the ear was associated with 1.9, 3.3, 5.8, 7.0, and 9.7 per cent additional breaks, respectively. There was an increasing rate of breakage of hybrids with increasingly more of their plants broken at 0.5 borer per plant. At 3.3 borers per plant, the average maximum number in the stalks below the ear, a total of 7.5, 13.6, 23.0, 32.6, and 52.2 per cent of the plants, respectively, were broken below the ear.

THE HARVEST OF EARS AND GRAIN.—The ears were harvested from October 13 to 18, and the yield of grain from each hybrid was calculated as bushels per acre on a 15.5-per cent moisture basis. In studying the effect of the borers on yield, the

Table 4.—Increase, B, of percentage of stalks broken below the ear with each additional borer per plant below the ear, and partition of sums of squares of Y, the percentage of breaks, after grouping hybrids in table 3.

Group Number	Mean Number of Borers per Plant	Mean Percentage of Breaks		Partition of Sum of Y^2			
	Below the Ear *X*	Below the Ear *Y*	Increase in Breaks *B*	Correction for *Y* (df=1)	Due to Regression (df=1)	Deviation from Regression (df=4)	Total
1	2.34	5.6	1.9± .42[1]	185	35	7	227
2	2.52	11.0	3.3± .91[1]	726	129	39	894
3	2.09	16.1	5.8±1.85[1]	1546	207	85	1838
4	2.16	24.5	7.0±1.23[2]	3602	509	64	4175
5	1.77	37.4	9.7±2.03[2]	8393	494	86	8973

[1] A significant value.
[2] A highly significant value.

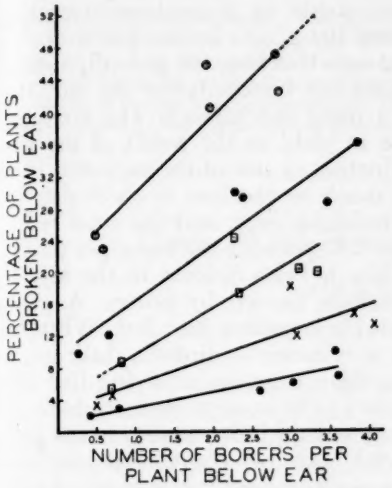

FIG. 1.—Regression of percentage of plants broken below the ear on number of European corn borers per plant below the ear for dent corn hybrids grouped according to the amount of breakage, Lafayette, Indiana, 1944.

numbers of borers in the entire plant were used because even the feeding on the leaf sheaths and blades by small larvae before many of them disappeared from the plants could cause material reduction in yield. The yields from each of the 16 hybrids are given by Deay *et al.* (1949). For the purposes of the present paper the average yields of the 16 hybrids were used.

A comparison was made of the loss of ears by stalk breakage with the loss in yield of shelled corn because of the general reduction in size of ears. The average yield of grain from the 16 hybrids decreased by linear regression from 62 to 50 bushels per acre as the number of borers per plant increased from 1.4 to 11.5. The reduction of 12 bushels, including unharvested ears, is 18.9 per cent of 63.6 bushels, the estimated yield in the absence of borers. An increase of 10.1 borers per plant thus caused a loss in yield of 1.87 per cent per borer per plant.

The ears of some of the plants broken below the ear touched the ground, and these were regarded as not harvestable by a mechanical corn picker. Where the number of borers in all the hybrids averaged 0.7 per plant within the stalk below the ear, 19 per cent of 283 plants broken below the ear had unharvestable ears compared with 12 per cent of 683 plants averaging 3.2 borers per plant. The increase of 2.5 borers was associated with an increase of 400 broken plants, of which 27 had unharvestable ears. Therefore, about 7 per cent of the increase in broken plants bore unharvestable ears. There were only 12 per cent of unharvestable ears at the highest levels of borers compared with 19 per cent at the lowest levels. Many of the most severely infested plants bore ears that would have been classed as nubbins, and it is possible that these ears did not reach the ground or cause the plants to break over far enough to reach the ground.

Few ears dropped to the ground from stalks not broken below the ear, as a result of borers feeding in the shanks. Only 0.6 per cent of the ears in rows 1 and 2 dropped to the ground compared with 1.6 per cent in rows 5 and 6. Hence, about 1 per cent of the ears dropped to the ground as a result of a maximum of about 0.7 borer per shank on September 9.

DISCUSSION.—Borer tunnels present favorable conditions for stalk rot infections, and corn strains susceptible to stalk rot would be expected to show the most breakage under borer infestation. Although the hybrids were not rated for diplodia stalk rot in 1944, Ullstrup (1943) has shown that line WF9 is resistant and R4 is susceptible to diplodia stalk rot. In the present study (Table 2) both lines were crossed on lines 187-2, P8, K230, and L317. The WF9-crosses averaged 4.3 per cent of their plants broken below the ear when infested with 0.5 borer per plant below the ear as compared with 17.6 per cent in the R4-crosses. Each additional borer per plant below the ear caused 3.3 ± 0.63 per cent additional breaks in the WF9-hybrids as compared with 7.0 ± 1.43 per cent in the R4-hybrids. In these respects the results were as expected.

Work by Sprague *et al.* (1946) resulted in a correlation between stalk breaking of single-cross hybrids at one locality having a natural infestation and a duplicate test at another locality in the absence of the borer. This correlation supported their belief that the hybrids most resistant to stalk breaking in the absence of the borer were also the most resistant under borer attack.

The borers caused an increase of 15.3 per cent in the plants broken below the ear, and 7 per cent of this increase had ears regarded as unmarketable because they were in contact with the ground. Also 1 per cent of the ears on unbroken plants were

on the ground. Therefore, there was an increase of 1.9 per cent in the number of plants that bore unharvestable ears. The borers caused a decrease of 18.9 per cent in the yield by reduction in size of ears, including the ears on the ground. If the unmarketable ears on the ground are considered a total loss, the loss in yield through reduction in size of ears was 10 times as much as the loss due to unmarketable ears.

There is no basis for comparing the amount of stalk breakage caused by the single-generation strain of the borer in Canada with that caused by the August generation of the multiple-generation strain in Indiana, because of the probable difference in the incidence of stalk rot diseases and in the habits of the larvae. In the Canadian fields there was a nearly constant borer population from July 21, or about 12 days after hatching, until September 12, or about 65 days after hatching, whereas in the Indiana field 40.4 per cent of the borers disappeared from the plants between September 9 and October 5, or about 33 to 59 days after hatching. Also the corn was in a different stage of growth at the time it became infested in the two localities.

SUMMARY.—The amount of stalk breakage below and above the ear, the number of borers in the ear shanks and the reduction in yield of grain caused by the August generation of the multiple-generation strain of the European corn borer, *Pyrausta nubilalis* (Hbn.), in 1944 were studied in a field of dent corn hybrids infested by hand with different numbers of egg masses.

An average increase of 10.1 borers per plant in 16 hybrids caused an increase of 15.3 per cent in the number of plants that broke below the ear, mostly owing to an increase of 2.8 borers per plant within the stalks below the ear; an increase of 38.9 per cent in the number of plants that broke above the ear, mostly owing to an increase of about the same number of borers within the stalks above the ear; and a decrease of 18.9 per cent of the total yield of those plants, including dropped ears and ears on broken stalks that touched the ground and were considered as not harvestable by a mechanical picker. Of every 100 plants broken below the ear, 7 had ears touching the ground, and of 100 plants not broken below the ear, the ear of 1 plant had fallen to the ground. The loss in yield as the result of the general reduction in size of the ears was 10 times as much as the loss in yield due to unharvestable ears, and the total reduction was 1.87 per cent per borer per plant.

The hybrids differed in the amount of breakage caused by borers. A group of hybrids involving line Ind. WF9, known to be resistant to diplodia stalk rot, broke less than a group involving line Ill. R4, known to be susceptible to diplodia. When the breakage below the ear in the presence of 0.5 borer per plant in the stalks below the ear averaged 2.2, 4.4, 6.8, 13 and 25 per cent in the different hybrids, each additional borer was associated with 1.9, 3.3, 5.8, 7.0, and 9.7 per cent additional breaks, respectively, an indication that each additional borer caused progressively more increase in breakage. The total breakage associated with 3.3 borers per plant in the stalks below the ear averaged 7.5, 13.6, 23.0, 32.6, and 52.2 per cent of the plants, respectively, in the different hybrids.

When tested in single-cross hybrid combination, the inbred lines Ind. P8, Ia. L304A, Kan. K230, and Ia. L317 were apparently more resistant to shank infestation than line Ind. WF9, CI. 187–2, and Ill. A, with line Ill. R4 somewhat less susceptible than WF9.

With the advance in the season there was a pronounced change in numbers of borers and their locations in the plants. While locations outside the stalks, such as in the ears and behind leaf sheaths, and locations inside the stalks above the ears were losing a total of 5.3 borers per plant between September 9 and October 5, there was an increase of 1.3 borers per plant inside the stalks below the ears. The difference of 4.0 borers, or 40.4 per cent of the total borers on September 9, disappeared from the plants. It is believed that before they did so, they materially reduced the yield of grain by feeding on the leaf sheaths and other leaf tissue.

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Tests With Insecticides for Hornworm Control on Tobacco

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The control of hornworms, tobacco hornworm, *Protoparce sexta* (Johan.), and the tomato hornworm, *P. quinquemaculata* (Haw.), is a major insect problem affecting the production of tobacco. The larvae consume large portions of the leaves and if not controlled will result in heavy losses. The tobacco hornworm is generally considered the more important in Virginia; however records indicate that the tomato hornworm is appearing in increasing numbers.

Experiments to find a more satisfactory insecticide for the control of hornworms on tobacco have been continued. Stanley (1950) reported that nitroparaffin and other new insecticides show a greater toxicity to the tobacco hornworm than lead arsenate. Previous work has been reported in an earlier paper (Dominick 1950). This paper is a report on materials and methods used for the control of first and second brood hornworms and incidental control of certain miscellaneous insects during 1950.

MATERIALS AND PROCEDURE.—Insecticides used were toxaphene 40 per cent wettable powder, toxaphene 10 per cent dust, toxaphene 10 per cent plus parathion 1 and 0.5 per cent dusts; TDE, which was used as a 5 and 10 per cent dust; a commercial material.[1] 5 per cent dust, prepared from a 50 per cent dust concentrate containing active ingredients consisting of one part 2-nitro-1,1-bis(p-chlorophenyl)propane and two parts 2-nitro-1,1-bis(p-chlorophenyl)butane; dieldrin, used as a 1 per cent dust and as 15 per cent wettable powder; DDT, as a 5 per cent dust, as 50 per cent wettable powder and as a 5 per cent dust plus 1 per cent parathion; heptachlor 5 per cent dust; parathion 1 per cent dust and cryolite containing 90 per cent sodium fluoaluminate.

Two experiments were conducted in which an effort was made to time the insecticide applications for the control of the first brood hornworms. The plots were one fifty-sixth of an acre in size, each replicated 4 times in randomized blocks. An untreated row separated the plots on either side. The sprays were applied with a single-nozzle sprayer of the knapsack type and the dusts with rotary-type dusters. The materials used and the rates of application are given in tables 1 and 2. The results were determined by making a count of all injured plants from the two center rows 18 days after the first treatment. A plant which had one or more leaves showing definate hornworm or budworm injury was scored as injured.

In the combination dust experiment, the dusts were prepared in the laboratory and applied two days later with rotary hand dusters. The plots were one sixtieth of an acre in size and were replicated 3 times in a randomized experiment. Two untreated rows separated the treated plots. Hornworms were counted on the two center rows of each plot before and 2 days following the treatment. The green peach aphid, *Myzus persicae* (Sulz.), population was determined by counting the aphids on five plants selected at random in each plot before and again 2 days following the treatment.

In the two experiments for the control of the second brood of hornworms, the plots were one fortieth and one eighth of an acre in size, respectively. The small plots were replicated three times and the

[1] Commercial Solvents Corporation, New York, N. Y.—*Dilan*. (Test Material #1 = TM-1).

Table 1.—Control of the first brood hornworms with DDT, TM-1, dieldrin and heptachlor.

Treatment	Rate per Acre in Pounds		Per Cent of Tobacco Plants Injured (June 29)	
	June 11, First Application	June 26, Second Application	Hornworms	Budworms
DDT, 5%	8	15	2.5	10.5
TM-1, 5%	8	15	4.0	9.0
Dieldrin, 1%	8	15	5.5	11.0
DDT, 2 lbs. 50% wettable powder	0.50	1	6.0	10.5
Dieldrin, 2 lbs. 15% wettable powder	0.50	1	9.0	16.0
Heptachlor, 5%	8	15	26.5	13.5
Check (untreated)	—	—	45.5	16.0

Table 2.—Control of the first brood hornworms with toxaphene, TM-1 and TDE.

Treatment	Rate per Acre in Pounds		Per Cent of Tobacco Plants Injured (June 30)	
	June 12, First Application	June 27, Second Application	Hornworms	Budworms
Toxaphene, 40% wettable powder	1	2	1.5	5.5
TDE, 10%	8	15	2.0	2.0
Toxaphene, 10%	8	15	3.0	6.5
TM-1, 5%	8	15	3.5	3.5
Check (untreated)	—	—	42.0	17.0

larger plots twice in randomized blocks. The hornworm infestation and the results were determined by counting the worms in random areas of the plots before and 2 and 4 days after treatment.

Early-Season Control.—The first application was made at a time when hornworm moth eggs and first instar worms began to appear in the various plots. The second application was made 15 days later. The species of hornworm present was largely the tomato hornworm as indicated by check plots and untreated buffer rows.

The data for the first experiment (Table 1), show that the percentage of plants injured by hornworms ranged from 2.5 per cent for the DDT 5-per cent dust treatment to 26.5 per cent for the heptachlor 5-per cent dust. With the exception of heptachlor, less hornworm injury occurred in plots treated with dusts than with sprays. The untreated check plots showed 45.5 per cent of the plants injured by hornworms. Although the treatments were not timed for the control of budworms, mostly *Heliothis armigera* (Hbn.), with the exception of the dieldrin spray treatment, all treated plots showed less injury than the checks.

The percentage hornworm injury (Table 2), ranged from 1.5 per cent for the toxaphene spray treatment to 3.5 per cent for the TM-1 5 per cent dust. The performance of the four treatments exhibited little variation. The untreated check plots showed 42 per cent injury by hornworms. Budworm injury ranged from 2 per cent for the TDE 10 per cent dust to 6.5 per cent for the toxaphene dust treatment. Budworm control in all treated plots was better than in untreated plots.

Combination Insecticides.—Inasmuch as hornworms and the green peach aphid are often a problem on tobacco at the same time, an experiment was undertaken to test combination materials for the control of these insects. Only dust treatments were used in the tests. The worms at the time were mostly in the fourth and fifth instars and were largely tomato hornworms. The green peach aphid population ranged from moderate to heavy. The insecticides indicated in table 3 were applied on July 5 at the rate of approximately 15 pounds per acre.

The results given in table 3 indicate that parathion 1-per cent dust applied alone was the least effective of the materials tested for hornworm control. A slightly higher percentage reduction occurred with the combination toxaphene plus parathion dust than with toxaphene 10 per cent dust. The highest percentage reduction was obtained with DDT 5 per cent plus 1 per cent parathion dust. The combination materials gave a similar control to parathion 1 per cent dust for the green peach aphid.

Late-Season Control.—Two comparative experiments were conducted on late-maturing tobacco for the control of the second brood of hornworms. In the first experiment, TDE 5 and 10 per cent and

Table 3.—Control of hornworms and aphids on tobacco.

Treatment	Pretreatment Counts		Per Cent Reduction (2 Days)	
	Hornworms	Aphids	Hornworms	Aphids
DDT, 5%, plus parathion, 1%	18	1299	96.1	99.7
Toxaphene, 10%, plus parathion, 1%	18	596	94.4	99.3
Toxaphene, 10%, plus parathion, 0.5%	29	731	93.3	98.6
Toxaphene, 10%	11	856	91.6	—
Parathion, 1%	10	663	53.3	99.9
Check (untreated)	22	1711	—	—

Table 4.—Comparative tests with TDE, TM-1 and toxaphene dusts against the second brood of hornworms.

Treatment	Pre-Treatment Hornworm Counts	Per Cent Reduction	
		2 Days	4 Days
TDE, 10%	38.2	97.4	100.0
TM-1, 5%	32.3	96.9	98.9
Toxaphene, 10%	34.6	94.2	97.1
TDE, 5%	30.0	91.9	100.0

Table 5.—Comparative control of the second brood hornworms with TDE, TM-1, toxaphene and cryolite.

Treatment	Pre-Treatment Hornworm Counts	Per Cent Reduction	
		2 Days	4 Days
TDE, 10%	46.0	96.7	100.0
TM-1, 5%	40.5	96.3	100.0
TDE, 5%	56.5	95.6	100.0
Toxaphene, 10%	34.0	94.1	100.0
Cryolite, 90%	40.0	63.7	90.0

TM-1 5-per cent dusts were compared with toxaphene 10 per cent dust. The dust applications were made on August 16 at approximately 20 pounds per acre. The hornworms present were largely *Protoparce sexta*, ranging in size from the first through the fifth instars. Approximately 25 per cent were fourth and fifth instar worms. In the second experiment TDE 5 and 10, toxaphene 10, and TM-1 5 per cent dusts were compared with undiluted cryolite dust. The dust applications were made on August 24 at approximately 25 pounds per acre. Pretreatment counts revealed that all stages of the two species of hornworms were present; however about 90 per cent were *P. sexta*. Approximately 50 per cent were in the fourth and fifth instars of their development.

The percentage reduction in hornworm population ranged from 91.9 per cent (Table 4), for the TDE 5-per cent dust to 97.4 per cent for the TDE 10-per cent dust. TM-1 5-per cent dust gave a slightly higher reduction than toxaphene 10-per cent dust. After 4 days, TDE 5 and 10-per cent dusts each gave complete control. The results indicate that TDE and TM-1 at rates used are apparently as effective as toxaphene 10-per cent dust.

The data for the second experiment (Table 5), show that TDE 5 and 10, toxaphene 10 and TM-1 5-per cent dusts gave a similar reduction in the hornworm population after 2 days. Each of the newer insecticides used gave more rapid control and was more effective than cryolite. The three organic insecticides resulted in complete control after 4 days, compared with 90 per cent for the cryolite dust.

SUMMARY.—In the control of the first brood hornworms, TDE, toxaphene, TM-1 and DDT resulted in satisfactory control of the tomato hornworm. A 5-per cent heptachlor dust was the least effective of the materials tested. All insecticides with the exception of the dieldrin spray treatment resulted in some reduction in the amount of budworm injury.

Toxaphene plus parathion and DDT plus parathion resulted in effective control of the tomato hornworm and the green peach aphid. A slightly higher reduction in hornworms was obtained when parathion was added to toxaphene than when toxaphene was used alone. Parathion 1 per cent dust was ineffective against fourth and fifth instar tomato hornworms, but gave near perfect control of the green peach aphid.

In late-season dust applications against the second brood hornworms, TDE, TM-1 and toxaphene gave effective control of all stages of hornworms. Cryolite was the least effective of the materials tested.

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DR. PAINTER TO GUATEMALA

Dr. R. H. Painter has been invited by the Iowa State College-Guatemala Tropical Research Center at Antigua to study at that station the insects which are injurious to corn in both Guatemala and the United States in the hope of securing information which can be used by farmers and plant breeders in both countries. Dr. Painter will make special search for strains of corn which are resistant to such insects as the southwestern corn borer, the European corn borer, the southern corn stalk borer and the corn ear earworm. Dr. Painter will spend six weeks, beginning early in August, on the project.

Effectiveness of Airplane Applications of Insecticides and Poison Baits for Control of Armyworm and Insecticide Residue Recovered at Harvest[1]

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During the summer of 1950 a severe outbreak of the armyworm, *Cirphis unipuncta*, was experienced in southern and central New Jersey. The first reports of the outbreak were received on June 12 and a survey showed a general infestation in all grains with severe injury in some fields where the insects had cut a high per cent of the nearly mature heads of barley and oats. The immediate use of poison bran bait was recommended as a control measure. Grower resistance to these recommendations was prompt and vociferous as they were of the opinion that the distribution of poison bran bait in nearly mature grain was a slow, laborious, old fashioned and impractical procedure. Most growers were of the opinion that airplane applications of DDT type insecticides was the only practical control measure for armyworm in grain. While such a program was not recommended it presented an opportunity to obtain information on the effectiveness of airplane applications of insecticides in the control of the armyworm, and to obtain information on the insecticide residues present on the grain and straw at harvest. We also had an opportunity to observe the effectiveness of hand and airplane distributed poison bran baits when many of the insecticide applications failed to give satisfactory control.

INFESTATION.—The armyworm infestation was general over the central and southern part of the state. There was considerable variation from field to field in the degree of infestation and in the age or size of the worms making up the infestations. The earliest pupation was noted in the southern part of the state on June 21 and pupation was completed during the first week of July.

FEEDING HABITS.—The armyworms were feeding on the lower leaves of grain and on the legumes, grasses and weeds growing in grain fields. In the nearly mature barley and oats, where the lower leaves had been eaten or were drying up, the armyworms fed on and cut off the heads of grain before migrating from the fields. In wheat fields which were 3 to 4 weeks from harvest the lower leaves of the grain provided sufficient food for the developing worms as there was only slight injury to the wheat heads and little migration of the worms from the wheat fields.

INSECTICIDES APPLIED BY AIRPLANE.—When it became apparent that airplane applications of insecticides would be used extensively against the armyworm, the growers were cautioned about the near maturity of barley and the objectionable insecticide residues on grain or straw that might be fed to dairy animals. Based on results obtained in some small plot tests and our experiences in past years with insecticide residues, 1 per cent parathion dust was suggested as a possible control measure where it was necessary to treat fields of barley.

The first efforts on the part of the growers to avoid harmful residues on barley was the use of airplane spray applications of TEPP. These treatments did not give satisfactory control and the spray program was quickly abandoned.

The airplane dusting program was inaugurated with the use of 3 per cent DDT at the rate of 25 pounds per acre. This dust combination was used rather extensively for a day or two, but was replaced by 5 per cent DDT and later by 10 per cent DDT when the first two concentrations of DDT failed to give satisfactory control. Toxaphene went through a similar period of adjustment and was finally used at a 10 per cent concentration. Parathion as a 1 per cent dust was used primarily on barley that was ready to harvest and apparently was not used at higher concentrations.

Standard bran and molasses baits containing 4 per cent paris green or 5 per cent toxaphene and distributed by hand were used in a limited way with excellent results. Later when there was a demand for

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EASTERN BRANCH PROGRAM, 1950.

airplane applications of poison baits a drier bait was prepared by reducing the molasses and water content of the standard bran bait which gave satisfactory results.

EFFECTIVENESS OF AIRPLANE APPLICATIONS OF INSECTICIDES.—It should be pointed out, that the severe injury to barley had brought home to the growers the need for immediate control of the armyworm in their wheat fields. The growers expected the new organic insecticides to give immediate kill of armyworms, and the effectiveness of an insecticide was judged on the presence or absence of dead worms in the field 24 hours after the application. With one or two exceptions, the growers were not satisfied with the control obtained with any of the airplane applications of insecticides. During the first few days of the outbreak it was not uncommon to find fields that had received several applications of insecticides in an effort to obtain immediate kill. With the growers in this state of mind it is not surprising that a switch was made to poison baits which gave a substantial kill during the first 24 hours.

Observations of the dusting and baiting operations and counts of dead worms were made in the fields throughout the period the control measures were being applied. Worm counts were made by collecting armyworms from 1.5 sq. ft. plots throughout the fields at various intervals following the insecticide application. General observations were also made of the amount of feeding that occurred following the application of the insecticide.

The following summary table gives the results obtained from observations and counts in 30 fields of wheat and barley.

DISCUSSION.—In barley fields, the poison baits were the only insecticide treatments that gave immediate control and stopped the cutting of the heads. Parathion gave immediate kill of the younger worms and stopped the older worms from feeding for one or two days, but did not entirely eliminate head cutting. DDT and toxaphene dusts did not prevent head cutting and gave a low kill of worms 72 hours after the dust application. With the exception of the fields treated with poison baits, most of the barley was harvested immediately to avoid excessive head cutting when the airplane dust applications failed to give immediate control of the armyworms.

In the wheat fields which were approximately a month from harvest, the growers were inclined to allow more time for an insecticide to be effective before they retreated the field and it was possible to observe the action of the insecticide over a longer period. In general, the effectiveness of the insecticides was the same as observed in the barley fields. Only the baits gave immediate kill of armyworms, as parathion was not applied to wheat fields.

The 3 per cent and 5 per cent dusts containing DDT and toxaphene when applied at the rate of 25 lbs. per acre gave a low kill of young worms and were generally non-effective against the older worms. The 10 per cent DDT and toxaphene dusts applied at the rate of 25 pounds per acre

Table 1.—Effectiveness of airplane applications of insecticides and poison baits in controlling armyworms.

INSECTICIDE	RATE PER ACRE	PER CENT KILL		REMARKS
		24 Hrs.	72 Hrs.	
TEPP Spray		0	0	Non-effective
3% DDT Dust	25 lbs.	0	0	Non-effective
5% DDT Dust	25 lbs.	0	25– 40	Non-effective
5% DDT Dust	40 lbs.	0	70– 90	1st, 2nd, 3rd instar worms readily killed. Older
10% DDT Dust	25 lbs.	0–70%[1]	70–100%[1]	worms alive after 72 hrs.
5% Toxaphene	25 lbs.	0	30– 50	Toxaphene kills slowly. Worms alive, but not
10% Toxaphene	25 lbs.	0	50– 90	feeding at 72 hrs.
1% Parathion	25 lbs.	50	60	Immediate kill of younger worms. Older worms alive, but not feeding at 72 hrs.
4% Paris Green Bran Molasses Bait	20–25 lbs.	75–90	90–100	Kills worms of all ages
5% Toxaphene Bran Molasses Bait	20–25 lbs.	75–90	90–100	

[1] 100% control was obtained in only one field.

Table 2.—DDT recovered from barley, wheat, rye and vetch, dusted by airplane.

Sample No.	Crop	Treatment	Applied	Harvested	Rain, Inches	(p.p.m.)	Gr. per Pound
1	Barley grain	10% DDT dust	6/19	6/28	0.48	7.71	.054
2	Barley straw		6/19	6/28	0.48	15.70	.110
3	Barley grain	5% DDT dust	6/16	6/28	0.56	3.29	.023
4	Barley straw		6/16	6/28	0.56	7.90	.055
5	Wheat grain	3% DDT dust 10% DDT dust	6/18 6/19	7.19	7.08	0	0
6	Wheat & Vetch grain	5% DDT dust	6/6	7/18	3.18	0	0
7	Wheat & Vetch straw		6/6	7/18	3.18	2.72	.019
8	Wheat & Vetch grain	5% DDT dust	6/9	7/25	4.72	0	0
9	Wheat & Vetch straw		6/9	7/25	4.72	0	0
10	Rye & Vetch grain	5% DDT dust	6/9	7/25	4.72	0	0

and 5 per cent DDT applied at the rate of 40 lbs. per acre gave a fair kill of the younger worms and stopped the older worms from feeding for a few days. Observations indicated that the older worms had obtained a sublethal dose of poison as they lay exposed on the ground and twisted and turned in an abnormal manner for several days. There was a low mortality in this group of worms and many resumed feeding and later started to pupate. Dust applications of toxaphene killed very slowly, few dead worms were observed during the first 72 hours although many of the worms were not feeding and apparently were affected by the poison.

Four per cent paris green and 5 per cent toxaphene bran molasses baits distributed by hand or airplane gave a clean up of armyworms in both barley and wheat fields in 24 to 72 hours. The standard bait formula used for hand distribution was modified as follows for distribution from airplane equipped with conventional insecticide dust hopper.

Standard Formula		*Airplane Formula*	
Bran	25 lbs.	Bran	25 lbs.
Paris green or Toxaphene	1 lb. 1.25 lb.	Paris green or Toxaphene	1 lb. 1.25 lbs.
Molasses	2 qts.	Molasses	1 qt.
Water	1–2 gals.	Water	¾ gal.

For airplane application a drier bait was required as the bait prepared by the standard formula, bridged over above the agitator and stuck to the sides of hopper. Many tons of the bait prepared by the modified formula were successfully distributed by planes with satisfactory results. Baits distributed by plane are broken up into individual particles and are more uniformly distributed through the field than is the case with hand distributed baits.

Our experience with poison bran baits indicates that 1.25 lbs. of toxaphene per acre is sufficient to give satisfactory control of armyworms in from 24 to 72 hours. The failure of airplane dust applications of toxaphene at the rate of 1.25 lbs. and 2.5 lbs. per acre to give satisfactory control emphasizes the importance of the proper placement of insecticides in controlling armyworms. During the period the dusts and baits were applied, light showers and drizzles of rain occurred on several days for an accumulated rainfall of approximately 0.5 inches. While the removal of dust deposits by rainfall might explain the unsatisfactory performance of the insecticides applied by airplane, this amount of rainfall did not seriously affect the performance of the poison bran baits.

INSECTICIDE RESIDUES AT HARVEST.—Samples of straw and grain for insecticide

Table 3.—Toxaphene recovered from barley and wheat.

Sample No.	Crop	Treatment	Applied	Harvested	Rain, Inches	(p.p.m.)	Gr. per Pound
11	Barley grain	5% bait scattered	6/19	6/28	0.48	1.29	.009
12	Barley straw	by hand	6/19	6/28	0.48	2.38	.017
13	Barley grain	5% dusted	6/20	7/ 1	0.48	6.86	.048
14	Wheat grain	5% dusted	6/14	7/28	7.86	0.13	.001
15	Wheat straw		6/14	7/28	7.86	0	0

Table 4.—Parathion recovered from barley dusted by airplane.

SAMPLE NO.	CROP	TREATMENT	APPLIED	HARVESTED	RAIN, INCHES	(p.p.m.)	Gr. per Pound
16	Barley grain	1% Parathion	6/20	6/28	0.48	.045	.0003
17	Barley straw	1% Parathion	6/20	6/28	0.48	.078	.0005

residue analysis were collected in the field as the crop was harvested and taken to the laboratory where they were analyzed.

CHEMICAL ANALYSES.—About 1 pound of fresh plant material was extracted with 500 to 1500 ml. of benzene, depending on the bulkiness of the sample, by shaking for about an hour. The solvent was filtered, decolorized and adequate aliquots were analyzed for the toxicant. Parathion was determined by the method developed by Averell & Norris (1948). For analyzing DDT the colorimetric method, worked out by Schechter (1945) and modified by Wichman *et al.* (1946) was followed. The arsenic from Paris green residues was determined by the Gutzeit method. Toxaphene was evaluated by the total organic chlorine method, using a procedure similar to that suggested for DDT, Fleck (1947). The difference between the total chlorine recovered from a treated crop and that found on a check sample from the same crop was multiplied by the factor 1.46. This factor is derived from the theoretical content of chlorine (68.54 per cent) in toxaphene ($C_{10}H_{10}Cl_1$), Roark (1950). Duplicate aliquots from each extract were analyzed. In some instances two or more samples were extracted, giving averages of several determinations for one treatment. The results are calculated in PPM and in grains per pound of plant material. The rainfall during periods from insecticide application to harvest was figured from records of official stations of the U.S. Weather Bureau, situated at or near areas where the crops were grown.

RESULTS.—Treatment, location of crops dates of application and harvest, accumulated rainfall and data from the chemical analyses are presented in tables 2 to 5 inclusive.

RESIDUES.—*DDT*—Dusts varying in concentrations from 3 to 10 per cent of technical DDT were applied by airplane on barley, wheat, rye and vetch. Of the five samples of grain analyzed, table 1, only the two barley samples showed appreciable amounts of DDT. Sample 1, dusted with 10 per cent DDT June 19 and harvested June 28 had 7.71 p.p.m., whereas sample 3 treated June 16 with 5 per cent DDT and harvested June 28, showed only 3.29 of the toxicant, In each case the rainfall approximated 0.5 in. Similar variations were also obtained in the straw from the two barley crops; 15.7 and 7.9 for samples 2 and 4 respectively. Apparently these differences are due primarily to the different concentrations of DDT in the dusts, since the methods of application and the rainfall were virtually the same in each case. No DDT was found on grain from wheat, vetch and rye crops.

The straw from wheat and vetch, sample 7, dusted with 5 per cent DDT June 18 and harvested July 25, showed 2.72 p.p.m. DDT, after 3.18 in. of rainfall. On the other hand, no DDT was found on straw from 5 per cent DDT, applied June 9 and harvested July 25, sample 9, after 4.72 inches of rain. The higher amount of rainfall may account for these differences.

Toxaphene.—Barley dusted by airplane with 5 per cent toxaphene June 19 and harvested July 1, showed 6.86 p.p.m. of the toxicant. No straw sample was avail-

Table 5.—As_2O_3 recovered from paris green bait on barley.

SAMPLE NO.	CROP	TREATMENT	APPLIED	HARVESTED	RAIN, INCHES	As_2O_3 (p.p.m.)	As_2O_3 Gr. per Pound
18	Barley grain	4% Paris green scattered by hand	6/19	6/28	0.48	0.5	.0035
19	Barley straw		6/19	6/28	0.48	3.15	.022

able from this crop. Another crop of barley baited with 5 per cent toxaphene, scattered by hand June 19 and harvested June 28, samples 11 and 12, contained only 1.29 and 2.38 p.p.m. toxaphene on grain and straw respectively. The rainfall was about 0.48 in. for each crop. A wheat crop dusted with 5 per cent toxaphene by airplane June 14, and harvested July 28, after 7.86 in. of rain, showed no toxicant on straw and only 0.13 on grain. These results suggest that application of bait by hand may leave less insecticide residue on crops than from airplane application.

Parathion.—Barley, dusted by airplane with 1 per cent parathion June 20 and harvested June 28, after 0.48 in. of rainfall, analyzed only .045 and .078 p.p.m. parathion on grain and straw respectively. This agrees with our previous findings, (Ginsburg *et al.* 1950), that parathion deposits rapidly disappear from crops exposed to weathering.

Paris Green.—Barley baited with 5 per cent paris green June 19 and harvested June 28 showed upon analysis the presence of As_2O_3 to the extent of 0.5 p.p.m. on grain and 3.15 p.p.m. on straw, table 5. These amounts are within the limits of arsenical tolerance allowable on crops. Evidently, scattering of paris green baits by hand appears to be safe from the arsenical residue standpoint.

In general, the amount of toxicants found on the crops at harvest varied with the following factors: (1) growth period elapsing between application and harvest; (2) concentration of insecticide in dust; (3) method of application; (4) and rainfall.

In all instances where appreciable amounts of insecticide residues were recovered, larger quantities were encountered on straw than on grain. This might be expected for the following reasons: 1.—Since the results are calculated on the basis of weight of sample, the straw, being lighter than the grain, has a larger surface area exposed to the dust and should therefore receive higher deposits; 2.—Less dust reaches the grain because it is completely or partially enclosed by a seed coat. one might expect the iusecticide residue on barley grain to be greater than other grains as the barley grain remains encased in the seed coat after threshing.

SUMMARY AND CONCLUSIONS.—Observations were made on the effectiveness of controlling the armyworm, *Cirphis unipuncta*, on field crops with the following insecticides dusted by airplane or scattered by hand as poison baits: DDT, parathion, paris green, and toxaphene. The crops under investigation were barley, rye, vetch, and wheat. Samples of straw and grain were collected at harvest and analyzed for insecticide residues.

Four per cent paris green and 5 per cent toxaphene poison bran baits at the rate of 20 to 25 lbs. per acre gave satisfactory control of armyworms in grain.

Airplane applications of 1 per cent parathion, 3 per cent DDT, 5 per cent DDT, 10 per cent DDT, 5 per cent toxaphene and 10 per cent toxaphene at the rate of 25 pounds per acre did not give satisfactory control of armyworms.

Barley dusted with DDT and toxaphene approximately 1 week before harvest showed appreciable insecticide residues on the grain and straw at harvest.

Barley treated with poison bran baits 1 week prior to harvest showed only slight residues at harvest.

Wheat dusted approximately 1 month before harvest and subjected to 3 to 7 inches of rain had little residue at harvest.

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The Toxicity of Eight Organic Insecticides to the Armyworm,

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During the early spring of 1949, armyworms occurred in outbreak numbers in Illinois for the first time since before DDT and the more recently developed insecticides became available. No data had been accumulated, therefore, on the effectiveness of any of these organic insecticides against armyworms in Illinois. Farmers were reluctant to accept the old, standard recommendation of poison baits for the control of this pest, as they had already been converted to the use of sprays in place of poison baits for grasshopper control. As a result, considerable spraying was done in 1949 without encouragement from state entomologists. DDT, chlordane, and toxaphene were the materials most commonly used. Results with both DDT and chlordane were variable, most farmers reporting poor control with both materials, but more of them were successful with chlordane than with DDT. Those who used toxaphene at 1.5 lbs. or more per acre generally obtained good control. In a more extensive outbreak in 1950, toxaphene at 1.5 lbs. per acre was widely recommended, and no failures to control were reported from its use in Illinois.

In order to obtain critical information on the relative toxicity to armyworms of some newer organic insecticides, dosage-mortality tests were initiated in the laboratory in 1949. The supply of larvae (from field infestations) was exhausted before definite results could be obtained in the 1949 studies. A second outbreak in 1950 provided material for completing the appraisal of the various materials under test. This paper presents evaluations of effectiveness of eight organic insecticides, based on LD-50 and LD-99 figures for the insecticides, both by contact and by stomach-poison action. In addition, the relative speed of action of the test materials is discussed briefly.

METHODS.—Larvae were collected from field infestations, brought to the laboratory in large mailing tubes supplied with food, and held until used in a refrigerator maintaining a temperature of 18° C. It was found that if the larvae were not crowded in the tubes, they could be kept vigorously alive for at least two weeks by removing them from the refrigerator once every two or three days, allowing them to feed at room temperature overnight, and then transferring all vigorous larvae to clean tubes with additional food before returning them to the refrigerator. Attempts to hold larvae continuously at usual refrigerator temperatures (5° to 10° C.) resulted in high mortality or loss of vigor. Inasmuch as armyworm outbreaks in Illinois are of relatively short duration, it was not possible to take the time necessary to explore various methods of storage in order to determine the ideal conditions, nor did we ascertain the limits of successful storage by the method we used. No larvae were stored longer than 16 days before being used in tests.

In general, the methods employed in these experiments were the same as those used in laboratory tests on grasshoppers reported by Weinman & Decker (1949).

Immediately previous to being used in a test, each larva was weighed on an analytical balance to the nearest milligram, after which it was placed in a cage made from a clean, one-pint, cardboard ice-cream container, both ends of which were replaced with screen wire.

In tests for contact effect, measured dosages of the compounds, dissolved in a 50–50 acetone-ethyl alcohol solution, were applied to the abdominal, sternal surfaces of the larvae by means of a micropipette, which consisted of a 0.25 cc. tuberculin syringe, the plunger of which was moved by a micrometer caliper graduated into thousandths of an inch. Each division on the micrometer scale delivered 0.23 mm.[3] of solution. After treatment the insects were returned to the individual cages, now supplied with suitable fresh food, in which they remained until they died or until the test was completed.

For testing stomach-poison effect, the same micropipette was used to deliver measured dosages of the solutions of test insecticides on 1-inch circles cut from

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Table 1.—L.D. 50 values (micrograms per gram of larval weight) and ratios to LD-50 of parathion for eight organic compounds, based on total data for all weights of larvae.

Compound	Contact		Stomach Poison	
	LD-50	Ratio to Parathion	LD-50	Ratio to Parathion
DDT	193.0	52.2	45.7	18.3
Chlordane	117.5	31.6	78.2	31.3
Toxaphene	56.2	15.2	34.1	13.6
Lindane	28.1	7.6	27.9	11.2
Aldrin	19.8	5.4	11.4	4.6
TM-1	8.8	2.4	11.5	4.6
Dieldrin	8.3	2.2	4.6	1.8
Parathion	3.7	1.0	2.5	1.0

corn leaves. By moving the leaf section as the liquid flowed out of the needle, a fairly uniform deposit could be spread over the leaf disc. After the solvent had evaporated, the treated leaf section was introduced into a cage containing a weighed larva. No other food was available to the insect for a period of 16 to 20 hours. At the end of that time, the remaining leaf fragment (if any) was measured, and the amounts of leaf and compound ingested were calculated.

In all tests, insects were examined and given fresh, untreated food daily for 6 days. Larvae used for controls were given comparable dosages of solvents or untreated leaf circles. Those worms which showed disease or parasitism during the period of observation were eliminated from the records.

At the end of the experiment, dosages were computed in micrograms, and the ratio of toxicant (in micrograms) to larval weight (in grams) was calculated for each individual tested. The results for each insecticide were tabulated in ascending order of dosage size, and averages of overlapping groups (Richardson, 1935) were plotted on log-probability paper, according to the method of Bliss (1938) As Bliss points out, this method is fairly accurate for the LD-50 value but is inadequate for determining the true slope of the curve. In order to calculate the LD-99 (or any other level of mortality), therefore, regression coefficients were calculated according to the method for curvilinear regression discussed by Snedecor (1937), from which values the complete curve can be constructed. With few exceptions, the LD-50 values determined by the method of Bliss were very near to those determined by computing the regression coefficient. Where only the LD-50 level is of interest, the probit method offers a much more rapid determination.

In the initial, exploratory work in 1949, approximately 1800 worms were used, and about 2000 individual insects were tested in 1950. The actual data presented in this paper are based entirely on the results of the 1950 tests.

Results.—After all of the tests had been run and the data assembled, an attempt was made to determine the LD-50 value for each insecticide, both as a contact and as a stomach poison. Using the probit method, we arrived at the values listed in table 1. A study of our data indicated rather clearly that too much heterogeneity existed, as evidenced by the number of points rather far removed from our projected line, both above and below the best possible fit. The most probable source of variation seemed to be the size of larvae used. It is rather generally recognized that body weight is not an ideal reference for dosage-mortality work, but it is a convenient reference and is better than none. Nevertheless, differences in

Table 2.—LD-50's and calculated LD-99's for eight organic insecticides tested against four arbitrary weight groups of armyworm larvae.

Compound	Contact								Stomach							
	LD-50 Wt. of Larvae in Mg.				LD-99 Wt. of Larvae in Mg.				LD-50 Wt. of Larvae in Mg.				LD-99 Wt. of Larvae in Mg.			
	150↓	151–250	251–350	351↑	150↓	151–250	251–350	351↑	150↓	151–250	251–350	351↑	150↓	151–250	251–350	351↑
DDT	114.0	123.0	273.0	365.0	450.0	770.0	1970.0	629.0	—	19.7	42.5	45.5	—	678.0	1100.0	374.0
Chlordane	172.0	53.2	149.0	—	346.0	229.0	1000.0	—	54.6	—	55.4	—	227.0	—	287.0	—
Toxaphene	33.7	49.8	58.2	67.0	111.0	184.0	283.0	160.0	<35.0	<46.0	39.8	49.8	—	—	110.0	145.0
Lindane	25.8	17.3	45.7	41.8	41.3	45.0	214.0	147.0	45.1	18.0	—	—	114.0	141.0	—	—
Aldrin	13.7	11.8	23.6	54.8	44.9	41.5	51.3	272.0	8.5	7.8	13.9	22.9	599.0	114.0	103.0	142.0
TM-1	9.6	6.6	15.5	24.9	15.1	18.2	53.2	339.0	<11.0	<15.0	<21.0	22.2	—	—	—	112.0
Dieldrin	7.8	6.8	11.0	13.9	35.0	16.1	25.0	45.0	3.9	3.5	5.7	7.8	21.0	12.6	22.4	18.0
Parathion	3.1	3.2	4.4	4.7	5.1	7.4	13.0	29.2	—	2.0	2.9	1.8	—	18.6	8.3	24.2

toxicity to different sizes of the same species have been reported (*e.g.* Fransen 1949), and the likelihood of a change in response to a toxicant with an increase in size of the insect seems greater when one is working with immature insects.

In order to test the validity of our hypothesis that much of the apparent heterogeneity of the data was due to differences in size of larvae, the summaries of results were reassembled into four arbitrary groupings based on weight of larvae: 150 mg. and below, 151 to 250 mg., 251 to 350 mg., and 351 mg. and above. As can readily be seen from table 2, which gives the LD-50 and calculated LD-99 for each compound and each weight group, there were definite differences in toxicity levels in the various weight groups. When the data were broken down into four groupings, there were too few individuals represented in some of the groups to permit an accurate determination of the LD-50 points; hence, the blank spaces and approximations in table 2.

DISCUSSION.—Based on the LD-50 values, parathion is obviously the most toxic insecticide included in these tests, both by stomach-poison and contact action, followed then by dieldrin, TM-1,[1] and aldrin. Lindane and toxaphene fall also in the range of the more effective materials, but DDT and chlordane, particularly as contact insecticides, are appreciably less toxic. All of the materials except lindane and possibly TM-1 are more toxic as stomach poisons than as contact insecticides. Dosages of lindane as high as 50 micrograms per gram gave insignificant kills of larvae weighing more than 250 mg.

The data show a trend toward decreasing toxicity with increasing size of larvae, although the smallest worms appear to be relatively more resistant than are the larger individuals to chlordane, lindane, aldrin, TM-1 and dieldrin. Fransen (1949) found that the toxicity of pyrethrum to gypsy-moth larvae increased with the age of the larvae, the youngest larvae being quite resistant. In his same tests, however, dinitro-*o*-cresol was toxic to young larvae but ineffective against larger individuals. This investigator also found differences in response to insecticides between larvae of the same age hatched at different dates. It is also possible (as has been repeatedly observed with two-spotted mites) that the type of food on which the test animal has been feeding will influence the response to various insecticides. At any rate, it is apparent that among larval Lepidoptera, one can not consider individuals of various sizes to constitute a homogeneous population, even though they are collected from the same field and are feeding on the same variety of plants.

Our results with parathion are in general agreement with the work of other investigators who have tested this compound against lepidopterous larvae. Parathion was found to be more effective than DDT against oriental fruit moth (Cochran 1949; Driggers & Merrill 1949, and others); Madsen & Borden (1949), working with the eye-spotted bud moth, concluded that parathion was more effective than DDT, TDE, toxaphene, or lead arsenate; and numerous workers have shown parathion to have exceptionally high toxicity to codling moth, red-banded leaf roller, grape berry moth, and corn borers. Parathion appears to be less effective (in field tests, at least) against corn earworm (Blanchard *et al.* 1946; Anderson & Haske 1949), although it was as good as DDT as a spray and better as a dust in tests by Wene & Blanchard (1950).

Packard (1946) reported poor kill with DDT sprays and dusts applied against field infestations of armyworms. Some other noctuid larvae, however, are quite susceptible to DDT. The fall armyworm, *Laphygma frugiperda*, is easily controlled with DDT (Hofmaster & Greenwood 1949), and Roney (1947) found DDT dusts to be completely effective against the beet armyworm, *L. exigua*. Various species of cutworms have been successfully controlled with formulations of DDT (Handford 1947, and others). Sun *et al.* (1948) found DDT to be more effective than γ-benzene hexachloride or chlordane against the southern armyworm as a contact poison, and it was second only to γ-benzene hexachloride as a stomach poison against this species. In these experiments, DDT was one-half as toxic as γ-benzene hexachloride, twice as toxic as chlordane, and five times as toxic as lead arsenate to southern armyworm as a stomach poison. Most of the work on cotton pests has shown chlordane, benzene hexachloride, and aldrin to have

[1] An eutectic mixture containing 33.3% 2-nitro-1,1-bis(*p*-chlorophenyl) propane and 66.7% 2-nitro-1,1-bis(*p*-chlorophenyl) butane. (*Dilan*)

Table 3.—Ratio, LD-50:LD-99, for eight organic insecticides; averages of results in various weight groups.

INSECTICIDE	CONTACT	STOMACH
DDT	4.7	22.8
Chlordane	4.9	4.7
Toxaphene	4.7	2.9
Lindane	3.2	5.1
Aldrin	3.7	24.7
TM-1	5.4	5.0
Dieldrin	3.1	3.8
Parathion	3.4	8.5

little effect on bollworm, but DDT, toxaphene, and dieldrin have given adequate control (Hanna & Gaines 1950, and others).

There is some indication in our data (Table 2) that the LD-50 dosage does not give the true picture of the probable relative effectiveness of these compounds under field conditions. In attempting to control a damaging pest, we are interested not in the dosage which will kill half the insects, but in one which will give virtually 100 per cent kill. By calculating the regression coefficients for each set of data, it was possible to arrive at a theoretical LD-99 dosage for each insecticide applied topically and by feeding to the various size groups of larvae—except, of course, for those groups in which there were too few data for reliable analyses.

In table 3 are listed the average ratios of the LD-50 dosages to the LD-99 dosages, both by contact and by stomach action for each insecticide. Since we have already shown that the various sizes of larvae do not constitute a homogeneous population, there is some doubt that an average based on results for the different weight groups is justifiable. It is conceivable that the variations in ratios, LD-50:LD-99, among the various weight groups for the same insecticides are physiological and not entirely due to normal experimental variation. Nevertheless, the averages used in table 3 should give a fairly true conception of the relative action of these materials at the two points on the dosage-mortality curves: A high ratio should mean that it would be difficult to get practical control except at dosages far in excess of those which might be expected from the relative toxicity of the compounds at their LD-50 level. If this assumption is valid, then toxaphene and dieldrin should give adequate control in the field at dosages only three to four times greater than that necessary to kill about half the larvae. By the same line of reasoning, it would be almost impossible ever to get adequate control with DDT, since as a stomach poison, at least, larvae would have to acquire 23 times as high a dosage for all of them to die as would be required to kill half of them, and the LD-50 value for DDT is relatively high, compared with the values for parathion, aldrin, and dieldrin. Actually, the LD-50 values for DDT and toxaphene are not greatly different; yet in the field, toxaphene has given consistently good results, but DDT has never given complete clean-up although it does kill a small to fair percentage of the larvae when applied at dosages of 1.5 to 2 lbs. per acre.

The speed of action of the insecticides included in these tests is not closely correlated with the relative toxicity to armyworm larvae. In table 4 are summarized the average rating on time of death of all larvae which died during the first 3 days

Table 4.—Relative speed of action of eight organic insecticides against armyworm larvae, based on death in 24 hrs.=20; death 2nd day=10.

	CONTACT					STOMACH				
	Weight Groups					Weight Groups				
COMPOUND	150 ↓	151–250	251–350	351 ↑	Average	150 ↓	151–250	251–350	351 ↑	Average
DDT	20.0	18.0	16.7	11.7	16.6	15.0	17.2	16.6	12.9	15.4
Chlordane	14.0	12.2	11.9	—	12.7	14.2	15.5	13.3	12.0	13.8
Toxaphene	13.4	14.6	11.8	9.8	12.4	18.0	12.5	12.6	9.5	13.2
Lindane	18.3	16.6	19.2	11.7	16.5	15.0	19.1	16.3	12.5	15.7
Aldrin	15.9	14.0	13.6	15.6	14.8	11.2	13.8	14.5	15.0	13.6
TM-1	19.1	19.6	18.2	17.5	18.6	17.3	17.1	17.7	16.0	17.0
Dieldrin	13.3	16.5	16.5	10.0	14.1	12.5	12.3	14.4	12.2	12.9
Parathion	18.3	18.8	18.2	20.0	18.8	15.0	18.3	15.6	18.2	16.8

after treatment, based on death in 24 hours equal to 20.0; death during second day, 10; death on third day, 5. Individuals which were moribund the day before they died were given a higher figure than those which were active until the day of death. From these data it can be seen that parathion and TM-1 gave the quickest kill, but DDT and lindane were faster in their action than were aldrin and dieldrin, even though aldrin and dieldrin are more toxic to armyworms than are DDT and lindane. In general, it took longer for the larger worms to die, regardless of the insecticide used, but aldrin and parathion are exceptions to this generality. Inasmuch as tests were checked only once a day, it is possible that there may be greater differences among these materials, since it was observed that parathion and lindane, by contact action especially, often produced toxic symptoms or death within a few hours after the larvae were treated, whereas few other compounds showed such effects until much later.

CONCLUSIONS.—Although toxaphene has given excellent field results against armyworms in Illinois during the past two seasons, several other materials seem worthy of field trials. Parathion, because of its high toxicity to these insects, would be considered most promising except that its known lack of residual action may work to its disadvantage in the field. Moreover, its high mammalian toxicity at the time of application causes one to look with more favor on the less hazardous materials which also may be effective at low dosages. Residues of insecticides on the crops rarely is an important consideration here, since under Illinois conditions, armyworms appear early in the spring, usually long before any crop is ready to harvest. When it is necessary to treat grass pastures for these pests, however, residues do, of course, have their usual importance.

If we assume that 1.5 lbs. per acre is the minimum effective dosage for toxaphene, then we should expect to get comparable results with dieldrin at about 3 oz. per acre, and with TM-1 and aldrin at 0.5 to 1 lb. Whether these materials will show an advantage over toxaphene in practice will depend both on performance under field conditions and on their relative price.

SUMMARY.—Laboratory tests were run on larvae of the armyworm to determine the LD-50 and LD-99 dosages for each of eight organic insecticides. These were evaluated both by contact and by stomach-poison action.

In order to relate dosage and mortality more accurately, it was found necessary to divide the data into groups based on four arbitrary weight classes of larvae. It was apparent that larvae of widely varying sizes from the same field did not respond in the same way to the same insecticide, even though the dosage was always related to the weight of the individual insects.

In contact effect, based on the LD-50 values, parathion was the most toxic insecticide, followed in order by dieldrin, TM-1, aldrin, lindane, toxaphene, chlordane and DDT. As stomach poisons, the order of relative toxicity was the same, except that DDT was more toxic than was chlordane.

Regression coefficients were calculated for each set of data so that the LD-99 level could be predicted with some accuracy. The ratio of LD-50 dosage to LD-99 dosage, which indicates the slope of the curve, showed a considerable variation among the several materials. Dieldrin, lindane, parathion and aldrin showed the flattest slope in contact effect, and toxaphene and dieldrin showed the flattest slope in stomach-poison action.

Parathion gave the fastest kill of larvae, with TM-1, lindane, and DDT following in that order.

Of the three materials, DDT, chlordane and toxaphene, extensively used in the field, toxaphene was definitely superior to the other two in control.

Parathion, dieldrin, TM-1 and aldrin seem worthy of consideration for field studies.

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Laboratory Tests of Allethrin for Stability, Residual Action and Toxicity[1,2]

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A synthetic compound combining the high insecticidal activity and low mammalian toxicity of natural pyrethrins has long been sought. Allethrin, the allyl homolog of Cinerin 1, because of its chemical relationship to pyrethrins and because of very promising results of initial tests against insects, approaches that goal. Other investigators have already discussed the chemistry of allethrin (Laforge *et al.* 1948, Schechter *et al.* 1949) and potential economic importance and relative toxicity to certain insects (Stoddard & Dove 1949; Moore 1950; Bishopp 1950). When a sample of this chemical was made available to this laboratory by the Carbide and Carbon Chemical Company in June 1949 an evaluation of it was begun against laboratory-reared insects. This evaluation consisted of tests against mosquito larvae, as a spray and as a residual treatment against adult house flies, and against roaches.

MOSQUITO LARVAE.—The initial tests with allethrin were against 3rd instar larvae of *Aedes aegypti* L. The median lethal dose in parts per million was determined from acetone solutions mixed with 100 ml. water containing 20 larvae per replicate. The tests were replicated at least four times. Comparison of 13 replicated tests of production batches of allethrin[4] with pyrethrins (a 20 per cent purified oil extract was used) revealed that at the LD 50 level allethrin was approximately one-third as toxic as pyrethrins to mosquito larvae, 0.19 ppm as compared to 0.059 p.p.m. This is shown in table 1.

In other larvicide tests the effect of combining these chemicals with synergists in the ratio of 1 part chemical, either allethrin or pyrethrins, to 5 parts synergist, either sulfoxide[5] or piperonyl butoxide,[6] was observed. The results are also shown in table 1 expressed as ppm of the active ingredient. It will be noted that slight improvement was obtained from such combinations. Perhaps a different ratio, or other synergists, will enhance this effect.

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology.

[2] Investigations conducted under a research fellowship sponsored by Carbide and Carbon Chemical Company, a division of Union Carbide and Carbon Corporation, at Rutgers University.

[3] Entomologist, State Science Service, Albany, N. Y.

[4] Comparison in this test and succeeding tests were made on the assumption that the production batches were 100% allethrin. Although several chemical analytical methods are known, further refinement of method is still being sought.

[5] "*Sulfox-cide*," n-octyl sulfoxide of isosafrole, obtained from S. B. Penick and Co.

[6] Piperonyl butoxide obtained from U. S. Industrial Chemicals Corp.

STABILITY TO LIGHT AND HEAT.—One of the first questions which arose during these early tests concerned the relative stability of allethrin and pyrethrins to light and heat. It was thought that, being a synthetic organic compound, allethrin might be less subject to breakdown than pyrethrins derived from natural sources. Exposure was accordingly made to ultra-violet light, heat, and to room conditions. Twenty ml. of 0.1 per cent aqueous emulsions made with 0.1 per cent commercial emulsifier were put in 250 ml. thin round quartz bottles and rotated 14 inches from an ultra-violet light furnished by a Cooper Hewitt Uviarc mercury lamp for 5 hours. In this way a layer of the solution was constantly exposed to the light. One hour's exposure is equivalent to approximately 1 day of mid-day sun. For the heat experiment, the solutions were put in bottles in an oven heated to 110° F. for 24 hours, and to 120 ° F. for an additional 48 hours. Exposure to room conditions of 70°–85° F. and window light in the quartz bottles was for 1 week. The results of tests with aliquots from these exposures and freshly made samples against mosquito larvae are indicated in table 2.

It will be observed that, when a freshly prepared aqueous emulsion was tried in this series, allethrin was about half as toxic as pyrethrins. This advantage of pyrethrins appears to be lost after exposure to ultraviolet light, heat or room conditions. Under ultra-violet light allethrin was 1.2 times as toxic as pyrethrins treated similarly; and when subjected to heat, almost 3 times as toxic as pyrethrins. Even under room conditions, allethrin was more than 1.3 times as toxic.

HOUSE FLIES.—An experiment similar to that just described was made against house flies except that the chemicals were exposed to the conditions as 0.1 per cent solutions in a highly refined kerosene oil. Three ml. of these solutions were then sprayed into a glass and wood chamber 5.5 feet high by 3 feet long by 2 feet wide after 50 to 100, five-day old, house flies were liberated in it. Tests were replicated at least three times and the results of 10-minute knockdown and 24 hour mortality observations are shown in table 3.

It will be noted that 10-minute knockdown remained above 90 per cent in all cases. At the dosage used, 24-hour kill of flies was not high for either chemical. However, the tendency was for allethrin, when fresh, to be superior to pyrethrins 39 per cent as compared to 23 per cent for pyrethrins; after subjection to heat, 28 per cent for allethrin as compared to 19 per cent for pyrethrins; and when exposed to room conditions, 30 per cent for allethrin as compared to 15 per cent for pyrethrins. After exposure to ultra-violet light, the oil solutions of the two chemicals caused about the same mortality.

THE RESIDUAL APPLICATIONS.—Because there was some indication that allethrin might be more persistent than pyrethrins, an attempt was made to determine the effect on house flies of periodic exposures to residual applications. Intial tests were made by brushing the desired amount of chemical from an acetone solution on freshly sanded 10-inch squares of plywood. Flies were exposed to the coated panels under cellophane-covered embroidery hoop cages described by Barber and Schmitt (1948). Subsequent tests were made by spreading the solution or aqueous emulsion evenly over the panels from a pipette. The flies were retained in contact with the treated surface for 2 hours, during which time the numbers incapacitated or knocked down were recorded. The flies were then removed, fed, and kept for 24 hours, a clean cardboard being used as the base for the cellophane hoop cage. Usually four replications were made for each test. Glass was also used as a surface for the chemicals. The panels were stored between testing periods in a vertical position in an artificially illuminated room held at 75° F.

Flies were exposed to the treated panels at periodic intervals up to 6 months. Results of tests of 144, 72, and 28 mg. per sq. ft. applications of allethrin and pyrethrin to plywood are shown in table 4. It may be noted here that in these and succeeding residual tests, untreated checks were run at the same time as the treatments. No knockdown was observed on the untreated checks and the 24-hour mortality ranged from 0 to 15 per cent.

It is apparent that under laboratory conditions of storage 144 mg. per sq. ft. of allethrin from an acetone solution remained effective on plywood for at least 3 months, declining to 75 per cent kill for a 28 mg. application tested after 1 month. Pyrethrins caused considerable knockdown

Table 1.—Toxicity tests with third instar mosquito larvae (*Aëdes aegypti*).

	LD 50 IN p.p.m.
Allethrin (13 tests of production batches)	0.19 ±0.03[3]
Allethrin 1 part plus Synergist[1] 5 parts	0.17
Allethrin 1 part plus Piperonyl butoxide[2] 5 parts	0.18
Pyrethrins (13 tests)	0.059±0.02[3]
Pyrethrins 1 part plus Synergist[1] 5 parts	0.04
Pyrethrins 1 part plus Piperonyl butoxide 5 parts	0.05

[1] *Sulfox-cide* obtained from S. B. Penick and Company.
[2] Piperonyl butoxide obtained from U. S. Industrial Chemicals Corp.
[3] Standard deviation.

up to the 1 month period from a 144 mg. application, but kill was poor even at the 1 week test for all doses.

At 144 mg. per sq. ft. in the emulsion form, allethrin was highly effective up to 3 months. At 6 months, knockdown was still good, but kill had declined to 70 per cent. Pyrethrins gave good knockdown up to 1 month, but kill was low.

Tests of residual applications to glass are shown in table 5. When applied in acetone, allethrin effectiveness lasted 2 months at 144 mg. and 1 week at the 36 mg. per sq. ft. level. Pyrethrins did not give any appreciable knockdown or kill at either dose even at the 1-week test.

In emulsion form, at the 144 mg. level, allethrin was effective for 3 months. The glass surface seemed to favor the emulsion of pyrethrins, since, unlike the acetone application, it was still providing 100 per cent knockdown and 90 per cent kill after 1 month. There was a sharp decline after this, and at the next periodic test both knockdown and kill were poor.

Combinations with synergists are of interest because they allow a reduction in the amount of the active ingredient. Table 6 shows the results obtained when two synergists were used. In the first series,

Table 2.—Stability tests[1] using third instar mosquito larvae (*Aëdes aegypti*).

	LD 50 IN p.p.m.			
	Fresh	U.V. Light, 5 Hrs.	Heat 110°–120° F., 3 Days	Room Conditions, 1 Week
Allethrin	.11	.53	.22	.36
Pyrethrins	.05	.65	.60	.59

[1] .1% Aqueous emulsions used.

allethrin and pyrethrin were used at 72 mg. in combination with sulfoxide at 360 mg. per sq. ft. Acetone solutions of such combinations applied to plywood resulted in definite boost in knockdown and kill and in extension of time of effectiveness. This was especially so for the mixture with pyrethrins.

In the other series of synergist tests, combinations were made with piperonyl butoxide at 288 mg. while the allethrin or pyrethrins were applied at 28 mg. per sq. ft. At this level the mortality from allethrin alone dropped off after 1 week, whereas when the synergist was used, mortality and knockdown was almost 100 per cent even at the 2-month test period. Although the mortality from the pyrethrins mixture was not so high as that from allethrin, pyrethrins plus synergist, too, were effective up to 2 months.

Some preliminary work was conducted with applications to painted surfaces. It was found that the allethrin residues do not appear to be so durable on some types of painted surfaces as on unpainted wood. In this connection it was noticed that the amount and kind of emulsifier used with emulsion applications might improve results. This is illustrated in table 7, in which results with an alkylated sulphate[1] as an emulsifier were better than those with three other emulsifiers. Further investigations to determine the effect of various surfaces on residual action are necessary.

One more series of residue tests are of

Table 3.—Stability tests[1] using 5-day-old house flies.

	FRESH		U.V. LIGHT, 5 HRS.		HEAT 110°–120° F., 3 DAYS		ROOM CONDITIONS, 1 WEEK	
	K.D. 10 Min.	Kill 24 Hrs.	K.D. 10 Min.	Kill 24 Hrs.	K.D. 10 Min.	Kill 24 Hrs.	K.D. 10 Min.	Kill 24 Hrs.
Allethrin	97	39	96	19	96	28	95	30
Pyrethrins	91	23	95	19	94	19	100	15

[1] 0.1% *Deobase oil* solution used.

Table 4.—Residual applications of acetone solutions and aqueous emulsions on plywood tested against house flies.

Chemical	Mg. per Sq. Ft.	Knockdown[1] and Per Cent Kill[2]									
		1 Wk.		1 Mo.		2 Mo.		3 Mo.		6 Mo.	
		K.D.	Kill	K.D.	Kill	K.D.	Kill	K.D.	Kill	K.D.	Kill
From Acetone Solutions											
Allethrin	144	A	90	A	99	B	100	B	100	A	68
	72	B	81	A	96	—	—	A	86	B	17
	28	A	94	A	75	—	—				
Pyrethrins	144	A	50	B	23	E	26				
	72	B	43	C	33	—	—				
	28	B	28	E	13	—	—				
From Aqueous Emulsions[3]											
Allethrin	144	A	—	B	97	—	—	A	100	A	70
Pyrethrins	144	A	—	B	23	C	30	—	—	—	—

[1] Knockdown Designations:
A = 100% down in 2 hrs.
B = 100% down but leg and wing movement noted
C = 50% down
D = 25% down
E = none down

[2] Per cent kill = 24 hours after flies were removed from the panels.
[3] 1% *Triton X-100* used as emulsifier.

interest. Plywood panels were coated with allethrin or pyrethrins at 144 mg. and 72 mg. per sq. ft. Half of each panel was exposed to ultra-violet light for 4, 9, 20 and 30 hours. The other half of the panel was covered to exclude the light so that direct comparison could be made of an exposed and an unexposed surface. The results are shown in table 8. The panels were wrapped in paper and stored in a box at room temperature between tests. It was found that pyrethrins were ineffective even in the initial test, but 20 to 30 hours of exposure to ultra-violet light was required to cause reduction in effectiveness of the allethrin at either level of application.

ROACH TEST.—A settling mist test was used to determine effectiveness against cockroaches. The test tower was a glass cylinder 38 inches tall and 10 inches wide. With a special nozzle, 1 ml. of an oil solution was sprayed into the chamber. A jar containing 5 or 10 insects was placed in an opening at the base of the tower. A metal slide protected the insects at the time of spraying. Immediately after spraying, the slide was withdrawn and the mist allowed to settle for 1 minute.

The results of tests with allethrin and pyrethrins in oil solution against female American roaches in which 20 to 40 roaches were used for each concentration are shown in table 9. It was found that

Table 5.—Residual applications of acetone solutions and aqueous emulsions on glass tested against house flies.

Chemical	Mg. per Sq. Ft.	Knockdown[1] and Per Cent Kill[2]									
		1 Wk.		1 Mo.		2 Mo.		3 Mo.		6 Mo.	
		K.D.	Kill	K.D.	Kill	K.D.	Kill	K.D.	Kill	K.D.	Kill
From Acetone Solution											
Allethrin	144	A	100	A	100	B	95	C	33	—	—
	36	B	97	E	36						
Pyrethrins	144	D	10	E	9						
	36	E	16	E	25						
From Aqueous Emulsion[3]											
Allethrin	144	A	100	A	100	A	100	A	100	E	0
Pyrethrins	144	A	100	A	90	C	28	E	7	E	0

[1,2] See notes Table 4. [3] 1% *Triton X-100* used as emulsifier.

Table 6.—Residual applications on plywood of acetone solutions containing synergists tested against house flies.

Chemical	Mg. per Sq. Ft.	Knockdown[1] and Per Cent Kill[2]									
		1 Wk.		1 Mo.		2 Mo.		3 Mo.		6 Mo.	
		K.D.	Kill	K.D.	Kill	K.D.	Kill	K.D.	Kill	K.D.	Kill
Allethrin	72	B	81	A	96	—	—	A	86	B	17
Allethrin plus synergist[3]	72 360	B	100	A	100	—	—	A	100		
Pyrethrins	72	B	43	C	33						
Pyrethrins plus synergist[3]	72 360	B	100	A	97	—	—	A	100	A	62
Allethrin	28	A	94	A	75						
Allethrin plus Piperonyl butoxide	28 288	A	100	A	99	A	99				
Pyrethrins	28	B	28	E	13						
Pyrethrins plus Piperonyl butoxide	28 288	A	100	A	94	A	87				

[1,2] See notes Table 4. [3] *Sulfoxcide*, S. B. Penick & Co.

Table 7.—Residual applications of allethrin emulsions to painted plywood; tested against house flies.

Allethrin, Mg./Sq. Ft.	Synergist		Emulsifier		Knockdown[1] and Per Cent Kill[2]					
					3 Days		1 Week		2 Weeks	
	Type[3]	Mg./Sq. Ft.	Type[4]	Per Cent Used	K.D.	Kill	K.D.	Kill	K.D.	Kill
On Oil Paint										
144	—	—	#1	1	A	100			B	74
On Cold Water Paint[5]										
28	PB	288	#1	1	D	8	D	12	E	26
28	PB	288	#2	1	B	82	D	66	D	4
28	S	576	#2	.1	—	—	C	39	—	—
28	S	576	#2	.1	—	—	C	16	—	—
28	S	576	#3	.1	—	—	B	37	—	—
28	S	576	#4	1	—	—	A	100	A	100
28	S	576	#4	.5	—	—	A	64	—	—
28	S	576	#4	.1	—	—	A	45	—	—

[1,2] See notes Table 4.
[3] Synergists PB = piperonyl butoxide.
S = Sulfox-cide
[4] Emulsifiers—#1 = *Triton X-100*, Rohm and Haas Co. #2 = *Tergitol 9*, Carbide and Carbon Chemicals Co. #3 = *Amine 220*, Carbide and Carbon Chemicals Co. #4 = *Orvus Paste*, Proctor and Gamble Co.
[5] Sears and Roebuck Co. Cold Water Paint.

Table 8.—Residual applications of acetone solutions on plywood to determine the effect of exposure to ultra-violet; tested against house flies.

Ultra-Violet Exposure	Time After Application	Allethrin, Mg./Sq. Ft.				Pyrethrins, Mg./Sq. Ft.			
		144		72		144		72	
Hours	Days	K.D.[1]	Kill[2]	K.D.	Kill	K.D.	Kill	K.D.	Kill
0	10	B	100	B	98	B	26	B	19
4	10	B	100	B	96	B	26	B	25
0	29	B	100	A	90	A	2	A	11
9	29	B	100	A	96	E	4	E	0
0	42	A	92	A	91	A	30	A	10
20	42	A	90	A	86	E	14	E	16
0	71	A	88	A	71	C	35	B	6
30	71	B	44	B	28	E	0	E	5

[1,2] See notes Table 4.

Table 9.—Settling mist tests against female American cockroaches.

CHEMICAL	CONCENTRATION, %	PER CENT DOWN, 30 MIN.	PER CENT KILL, 4 DAYS
Allethrin	1.6	95	85
	1.2	65	40
	.8	15	10
	.4	0	0
Pyrethrins	.4	100	80
	.3	100	65
	.2	70	35
Oil (*Deobase*)	100	0	0

Table 10.—Settling mist tests against female German cockroaches.

CHEMICAL	CONCENTRATION, %	PER CENT DOWN, 10 MIN.	PER CENT KILL, 2 DAYS
Allethrin	.2	79	70
	.1	70	63
	.05	61	56
Pyrethrins	.2	100	91
	.1	100	70
	.05	100	70
Oil (*Deobase*)	100	0	26

the dose of allethrin required to produce comparable mortality results was 4 to 6 times that of pyrethrins.

Similar series of tests against German roaches are shown in table 10. At each concentration shown, 80 roaches were used. Allethrin was found to be slower in knockdown than pyrethrins and 0.7 to 0.9 as effective in the 48 hour mortality test.

SUMMARY AND CONCLUSIONS.—Initial tests with allethrin against mosquito larvae indicated that it was one-half to one third as toxic as pyrethrins, but that when exposed to ultra-violet light, or heat in the laboratory, allethrin is less subject to breakdown. Against house flies in an oil spray, allethrin was as toxic as pyrethrins when fresh and retained its effectiveness better than pyrethrins after subjection to light or storage in glass under room conditions. These tests led to an investigation of residual applications to plywood and glass. From acetone or water emulsion solutions, it was found that allethrin residues at 144 mg. per sq. ft. persisted for several months against house flies. Pyrethrins caused knockdown of flies up to 1 month after application, but the flies recovered from such residues when tested 1 week after application. When allethrin was combined with a synergist, the amount of residue could be reduced to 28 mg. per sq. ft. The residual action of the pyrethrins was also markedly improved.

Allethrin emulsions applied to some types of painted surfaces were not as durable as those on unpainted wood. The emulsifier used may influence effectiveness.

When residues of 144 and 72 mg. per sq. ft. were exposed to ultra-violet light, up to 30 hours of exposure was necessary to affect the allethrin residue, whereas pyrethrins were relatively ineffective when fresh.

In a settling mist test against female American roaches 4 to 6 times the dose of allethrin is needed to give the same mortality as pyrethrins, whereas against German roaches allethrin was found to be 0.7 to 0.9 as effective as pyrethrins.

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DR. LAAKE TO COSTA RICA

Dr. E. V. Laake who has been in charge of the laboratory of the Bureau of Entomology and Plant Quarantine established at Kerrville, Texas, for the study of pests of livestock, has been assigned, at the request of the government of Costa Rica, to assist the government in the development of materials and methods for the control of animal parasites in Costa Rica.

Dr. Laake is doubtless in his new location at this time as he planned to leave for his headquarters in San Jose on July 19.

The Role of the Circulatory and Nervous Systems in the Toxic Action of Parathion[1]

H. J. Ball and S. D. Beck,[2] *University of Wisconsin, Madison*

Since the introduction of parathion as an insecticide, comparatively little work has been undertaken to elucidate the mechanism of its distribution within the insect body. Roan *et al.* (1950) suggested that the blood plasma might be the means of transport in the American roach. In the following study, nerve tissue as well as blood was found to be involved in the translocation of the toxic principle. The American roach, *Periplaneta americana* (L.), was used exclusively as the test animal.

The studies on nerve tissue were made using both cauterization and transection techniques to interrupt a nerve between the point of application and thoracic and cephalic centers of the central nervous system. Such techniques are not new and have been used by several workers on various insecticides. Hutzel (1942) applied surgical techniques to the ventral nerve cord in studying the paralytic effects of pyrethrins. Yaeger & Munson (1945) used cautery of nerve tissue as a tool in studying effects of DDT poisoning, and Tobias & Kollros (1946) transected both peripheral nerves and the ventral nerve cord in work on the loci of action of DDT. Various techniques of nerve interruption as used in this study are explained in the appropriate section.

The analytical method used for estimation of small amounts of parathion was essentially the one described by Averell and Norris (1948). However, the range was reduced from 20–200 μg. to 2–20 μg. of parathion by cutting down the required reagents proportionately. Careful manipulation of the technique resulted in satisfactory analytical results down to 2 μg. of parathion.

Table 1.—Knockdown time of female American roaches treated with 200 μg. of parathion per gram of body weight.

Area Treated	Avg. Knockdown Time (Min.)
Vertex	90.2
Mesosternite	110.0
Second sternite	120.0
Fourth sternite	154.3
Sixth sternite	185.0
Fourth tergite	212.6

Early Experiments.—Since it is generally known that the nervous system is involved in the production of characteristic reactions of an insect to parathion, a question arose as to the relationship between knockdown time and the relative distance of application site from the central nervous system.

In an attempt to find an answer to this question, female American roaches were treated topically with parathion in acetone solution at a rate of 200 μg. per gram of body weight. Areas treated are indicated in table 1. The treatments were replicated two times and the experiment repeated three times. The knockdown time in minutes is that time required for general paralysis with the "neck" in a distended or stretched condition. This symptom was used as the end point in determining knockdown time because of its constant occurrence during the course of parathion poisoning.

The data in the above table indicate that a direct relationship exists between proximity of the treated area to tissue of the central nervous system and the time required for knockdown. If the blood were a more effective agent for the translocation of parathion than nerve tissue within the insect, those insects receiving treatment immediately over the dorsal vessel should have had shorter knockdown times whereas insects treated dorsally had the longest knockdown times.

The finding that knockdown time was influenced by site of application suggested the possibility that cuticle thickness might also be of importance. The experiment described above was repeated, and cuticle measurements of the treated areas were made. The results showed that no correlation existed between knockdown time and cuticle thickness. The lack of correlation between cuticle thickness and permeability to a toxicant has been observed by previous workers (Ricks & Hoskins, 1948,

[1] Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

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and Richards & Fan, 1949). The correlation between knockdown time and the proximity of the treated area to the central nervous system was again evident.

The general conclusion reached in these early experiments was that the central nervous system was important in the toxic action of parathion, and that knockdown time could be correlated with the relative distance of the treated area from the central nervous system. Also, some mechanism other than the blood appeared to be involved in the movement of the toxic action of parathion.

NERVE TRANSECTION EXPERIMENTS.—Since the proximity of the central nervous system to an area treated with parathion appeared to be important in the production of characteristic reactions of the animal to the insecticide, the possibility that removal of a part of the nervous system might delay those characteristic reactions following treatment was examined.

Early experiments indicated that when the ventral nerve cord was interrupted by burning in the first abdominal sternite and treatment with parathion was made on the third abdominal sternite, the knockdown time was increased as compared to control insects which were not burned. Similar results were obtained when the nerve cord in the second or third abdominal sternites was cut by burning and treatment made with parathion on the fourth and fifth abdominal segments respectively. As the number of burned areas was increased, the time between treatment and knockdown was also increased. Table 2 shows these data.

The same increase in knockdown time was found to exist when the peripheral nerve of the metathoracic leg was transected in the coxal area by cutting, and parathion treatment was made on the tibia. Similar results were obtained when the cercal nerve was interrupted by burning and treatment was made on a cercus. Table 3 shows typical results for these experiments. "Cercal burn" in the table below indicates that the burn was made at the junction of the cercal nerves with the ventral nerve cord.

These results show that when the nerve continuity is interrupted in the ventral nerve cord proper, a peripheral leg nerve, or the cercal nerve, and treatment is made dostal to that interruption, the knockdown time is increased as compared to control insects. Burnings made in other areas, such as the dorsal vessel and the lateral body wall, showed no such increase in knockdown time. Congo red dye injections made in the abdomen and collected from the antennae showed that such burnings did not interfere appreciably with normal circulation.

The data obtained indicate that the central nervous system may be important in the translocation of the toxic principle from the site of application to the loci action. This interpretation is based on the finding that breaking the continuity of nerve tissue in some way delayed the toxic activity of parathion. The circulatory system appears to be of secondary importance in the translocation of parathion.

RATE OF MOVEMENT ALONG NERVE TISSUE.—Since previous experiments showed that nerve tissue was involved in the transfer of parathion or its toxic metabolites to the loci of action, it was considered important to attempt to determine the relative speed of movement or progression of this toxic activity along the ventral nerve cord.

Table 2.—Effects of burning the ventral nerve cord on knockdown times in American roaches treated with parathion.

AREA OF NERVOUS SYSTEM REMOVED	KNOCK-DOWN (MINUTES)
Control—none	31
First abdominal sternite	37
First and second abdominal sternites	60
First, second, and fourth abdominal sternites	150

Table 3.—Knockdown times in minutes following burning of cercal nerve in female American roaches treated with 100 μg. of parathion per gram of body weight.

AREA BURNED	KNOCKDOWN (MINUTES)	KNOCKDOWN (MINUTES)
Cercal burn		
1	261	
2	308	292
3	308	
Control—		
(no burn)		
1	69	
2	92	92
3	117	

Male roaches of uniform weight were treated topically with 50 μg. of parathion in acetone solution between the sixth and seventh sternites over the ventral nerve cord. Following treatment, the sections of nerve cord were removed at intervals of 5, 10, and 20 minutes. By the following technique roaches were anaesthetized and pinned ventral side up in a dissecting dish. After covering the sterna of segments 1 to 7 with a thin layer of wax, a rectangular area of cuticle, 2 by 4 mm., was removed from the fifth sternite to expose the ventral nerve cord. A ganglion, along with a small part of the ventral nerve cord on either side, was cut away. The cuticle was then replaced and waxed into position. Control insects so treated showed no ill affects even five days following the operation.

Another group of roaches designated in the table as time 0, had the nerve cord removed immediately preceding treatment. Table 4 shows the average results for three experiments, the treatments being replicated two times.

Inspection of table 4 shows that a definite relationship appears to exist between knockdown time and the number of minutes allowed to elapse between treatment and removal of nerve tissue. Insects in which the ventral nerve cord was sectioned preceding treatment showed the longest knockdown time. As the time interval between treatment and nerve cord removal increased, knockdown time decreased. Here again it appears evident that the ventral nerve cord is involved in the transport of parathion, or one of its toxic derivatives.

IN VITRO ABSORPTION OF PARATHION BY VARIOUS TISSUES.—Before proceeding with experiments devised to determine amounts of parathion present in nerve and other tissues following topical application, it appeared necessary first to ascertain to what degree absorption took place *in vitro*.

From a group of American roaches, 100 mg. each of nerve, muscle, and fat tissue was obtained by dissection. Following dissection, each tissue was homogenized, placed in a 0.2 per cent parathion emulsion for 12 hours, washed thoroughly to remove surface material, and re-homogenized with small aliquots of benzene to extract the absorbed parathion. After evaporating the extracts to equal volumes, smaller volumes were used to determine relative knockdown times when applied to adult roaches. Comparative knockdown times are indicated in table 5 below.

Under *in vitro* conditions, these results would indicate that nerve tissue is capable of absorbing parathion in greater amounts than is either fat or muscle.

IN VITRO ABSORPTION OF PARATHION BY VARIOUS TISSUES.—The results of the preceding experiments indicated that nerve tissue was directly involved in the movement of parathion within the body, and that nerve tissue, as well as muscle and fat, had the capacity to absorb parathion from a surrounding medium containing this toxicant. Therefore, the accumulation of parathion in the central nervous system as well as in other tissues following topical application was investigated.

Nerve tissue.—Each of 10 adult American roaches was treated with 200 μg. of parathion on the fifth abdominal sternite. At the first appearance of symptoms, the roaches were sacrificed and the ventral nerve cords removed. The nerve tissue was homogenized in three successive three milliliter aliquots of benzene, and the homogenate was filtered. An additional milliliter of benzene was used to wash out the homogenizing tube and nerve tissue residue. The benzene filtrate

Table 4.—Knockdown times of male roaches treated with 50 μg. of parathion. Ventral nerve cord removed at times indicated following treatment.

TIME FOR REMOVAL	KNOCKDOWN TIME			KNOCKDOWN TIME
	1	2	3	
(min.)	(min.)	(min.)	(min.)	(min.)
0	344	304	245	298
5	272	166	186	208
10	220	189	120	176
20	125	225	144	165

Table 5.—Comparative knockdown times for insects treated with a benzene extract of parathion from nerve, muscle, and fat tissue.

TISSUE EXTRACTED	AVG. TIME
	(min.)
Nerve	60.7
Muscle	83.9
Fat	89.4

then totaled 10 milliliters. Exactly the same procedure was used to obtain a nerve tissue extract from 10 untreated roaches.

These two extracts, a 10 milliliter benzene blank, and a 10 milliliter benzene sample containing 8 μg. of parathion, were then evaporated to dryness and analyzed for parathion. No detectable amounts of parathion were recovered from the extracts. Biological tests used to assay the extracts with roaches and houseflies also showed no detectable parathion.

Both the bioassay and the microanalytical experiments showed that no significant amounts of parathion were detected in the ventral nerve cord following topical treatment with the toxicant. Results of previous *in vitro* experiments indicated that nerve tissue was capable of absorbing parathion. It is possible to postulate from this evidence that parathion is metabolized in nerve tissue, and therefore does not persist as such.

Foregut assays.—Abott (1926), working with *Periplaneta australasiae* Fab., found that the foregut, and especially the crop, was an important organ for the absorption of fats from the hemolymph. Abott also noted that the crop was permeable to fat and fat solvents. Since parathion is a fat soluble insecticide it seemed possible that the foregut could remove parathion from the hemolymph and as such would be a region of accumulation or excretion for this toxicant.

The foreguts of 10 roaches each treated topically on the fifth sternite with 200 μg. of parathion in acetone solution were removed at the first sign of intoxication. Any gut contents were removed by several washings in distilled water and the foregut tissue was then homogenized and treated exactly as the nerve tissue in the preceding experiment. Again, foreguts of untreated insects, a benzene blank, and a known amount of parathion were assayed chemically. The average amount of parathion in the foregut tissue for three experiments was 14.77 μg. for treated roaches and 0.88 μg. for untreated insects. It thus appeared that the foregut was removing parathion from the hemolymph of the insect.

In order to learn more about this phenomenon, the experiment was repeated with several variations. Roaches were treated with 200 μg. of parathion as before. At intervals following treatment of 5, 10, 15, and 20 minutes, groups of 10 roaches were sacrificed and the foreguts removed and analyzed as before. The results of four experiments are indicated in table 6.

Table 6.—Parathion recovered from foregut tissue of American roaches treated topically with 200 μg. of parathion at times indicated.

Time Interval between Treatment and Foregut Removal				
0 min.	5 min.	10 min.	15 min.	20 min.
(μg.)	(μg.)	(μg.)	(μg.)	(μg.)
1.7	15.3	21.4	36.5	24.0
0.0	6.3	9.7	28.1	—
2.7	—	14.5	48.1	60.2
3.2	—	—	54.3	69.7
1.9	10.8	15.2	41.5	51.3

The above data indicate not only that parathion was taken up by the foregut, but that a direct relationship existed between the amount of parathion present and the time elapsing between treatment and dissection. Roan *et al.* (1950), using tetraethyl pyrophosphate containing the radioactive isotope P^{32}, found that P^{32} also accumulated in the foregut. Since tetraethyl pyrophosphate is more soluble in water (and probably insect blood) than is parathion, the means of transport in the case of tetraethyl pyrophosphate and other blood-soluble toxicants is more easily explained. Transport of parathion in the blood is considered in a following section.

Assays of blood.—Although previous work pointed to the fact that the toxic action of parathion movement was probably limited to the ventral nerve cord, and other large nerves, the blood has not been excluded as a carrier of parathion. Consequently, the following experiments were carried out.

Two groups of 10 roaches each were used. Each insect in one group was treated with 200 μg. of parathion in acetone solution on the fifth abdominal sternite. Fifteen minutes following treatment, at which time the foregut has been shown to have absorbed an average of about 40 μg. of parathion per 10 insects, the antennae were clipped off near their base and the blood collected in a small watch glass. If the blood was kept flowing and the drops were removed as they

accumulated, 0.15 to 0.20 cc. of blood could be collected from 10 roaches. The same procedure was used for the untreated insects, except that no time limit was involved.

The blood aggregations from treated and untreated roaches were homogenized individually and extracted as in the two preceding experiments. The experiment was conducted three times and the average amount of parathion in the blood of the ten treated insects was found to be 2.5 micrograms.

Thus, it appeared that the blood carried only small amounts of parathion. The amount of parathion found in the blood at any one time was approximately one fourth the amount found in the foregut 5 minutes following treatment with an equal amount of toxicant.

PARABIOTIC EXPERIMENTS INVOLVING TRANSPORT OF PARATHION IN BLOOD.—Previous experiments have indicated that the blood was involved in the translocation of small amounts of parathion. This was proved to be so by analytical analysis of the blood. Also, the foregut has been shown to accumulate parathion. Therefore, it appeared that the blood might be responsible for the continuous movement of small amounts of parathion from the point of application to the foregut.

In order to determine the role of the blood in translocation of parathion, parabiotic experiments were conducted. The only necessary requirement was that the two insects make contact only through the blood. A technique described by Bodenstein was used and is essentially the one indicated below.

The pronota of two adult American roaches were covered with a thin layer of wax. A triangular area of pronotal cuticle, approximately 4 mm. on a side, was then removed from each roach. In one insect, the apex of the triangle was anterior while in the other insect the apex was posterior. The two insects were then turned back to back and the two triangular openings were placed in juxtaposition. The edges of the triangles were then sealed with liquid wax and a blood-tight connection resulted between the two insects. As the wax layers separated the two insects, a tissue to tissue contact was avoided. Both insects were then placed in a wax-bottomed petri dish. The bottom roach was placed in a normal standing position while a small wax block the same thickness as the bottom roach held the top roach in position for testing. Congo red dye injected into the coxae of either roach was easily detected in the antennal blood of the other. This indicated that a blood connection existed and that continuity of the two hemocoels existed. With this arrangement, verification of parathion translocation by the blood was carried out.

Ten pairs of roaches were prepared as described above. One insect of each pair was treated topically with 100 μg. of parathion in acetone solution on the fifth abdominal sternite. When the untreated insects showed definite symptoms of parathion poisoning, the preparations were taken down and the entire digestive tracts were removed. The intestinal lumens were cleaned and the intestinal tissue was homogenized and extracted with absolute ethyl alcohol and processed according to the usual analytical procedure. In the three experiments, each involving 10 pairs of roaches, the gut tissue for treated insects yielded an average of 10.33 μg. of parathion, and the gut tissue of untreated roaches was found to contain 12.66 μg. It was believed that the difference which existed here was not significant as the limit of the analytical method was approximately 2 μg. However, the results show that parathion was carried through the blood from the treated to the untreated insects and that the foreguts in the untreated roaches were able to remove parathion from the blood. These results, based on a parabiotic arrangement which excluded any tissue contact except blood, are considered conclusive evidence that parathion is carried in the blood, and is removed from the blood by the foregut.

DISCUSSION.—Although a considerable amount of literature is available concerning the toxic effects of various insecticides, little information is to be found regarding their translocation or movement within the insect body. That the blood may be involved in the transport of parathion within the insect body was suggested by Roan *et al.* (1950) and was proved by the present writers' results. That the central nervous system is also of great importance in the translocation of parathion seems probable in light of some of the results obtained. It would appear that two separate mechanisms exist for the

translocation of parathion in the insect body. One is the central nervous system (especially the ventral nerve cord) which transports very small amounts of the toxicant or its metabolite(s). The other mechanism is the blood.

Translocation in the blood functions as follows. Following penetration of the cuticle, the blood absorbs only small quantities of parathion. Due to the low solubility of parathion in aqueous solutions, lipomicra in the blood may be responsible for absorbing and transporting small quantities of parathion to the various parts of the body, including the foregut where it is excreted. Abott (1926) has shown that the foregut is an important organ for the absorption of fat-soluble substances from the blood.

Translocation in the blood is considered secondary for the following reasons. Knockdown time was lengthened in those insects whose ventral nerve continuity was interrupted. Roaches undergoing similar surgery but in which the nerve cord was not transected acted as controls and the knockdown times were similar to those of normal insects. This would indicate that translocation via the blood was less important to the toxic effects then movement through the ventral nerve cord. Since detectable amounts of parathion were found in the foregut even five minutes following application, the blood had the capacity to transport significant amounts of parathion.

The role of the central nervous system in this translocation process is dependent upon the ability of nerve tissue to absorb parathion from the surrounding tissue. That this is physically possible has been shown by *in vitro* experiments. Hutzel (1942) showed that adipose tissue may be involved in conducting pyrethrum from the basement membrane to the ganglia or ventral nerve cord. Richards & Weygandt (1945) found that lipid-soluble materials, and especially those with low water solubility, accumulated in insect nerve tissue. It is reasonable, then, to assume that a similar mechanism can function for the absorption of parathion by nerve tissue. Following absorption by the ventral nerve cord, a wave of toxic activity progressed up the ventral nerve cord. This conclusion is based on the results of several of the preceding experiments. What appears to be an actual translocation or movement of toxic activity along the ventral nerve cord may be a destructive reaction propagated by toxic metabolites. This would account for the so-called "movement" along the ventral nerve cord.

In previous experiments, knockdown times indicated that an indirect relationship existed between knockdown time and the time interval between treatment and nerve transection. It appeared that the knockdown differences were probably a result of the time which elapsed between treatment and transection of the ventral nerve cord. This would allow the translocation or progression of activity of parathion along the ventral nerve cord to proceed farther anteriorly before transection was made. Since the rate of movement across the break in the ventral nerve cord should be constant, and effected by the blood, it was concluded that parathion or one of its toxic metabolites was translocated more effectively in the central nervous system than in the blood.

From the previous experiments carried out to determine parathion absorption by nerve tissue *in vitro*, as well as the work previously described by Hutzel (1942) and Richards & Weygandt (1945), it seems clear that parathion is absorbed by the central nervous system. However, attempts to find parathion in nerve tissue from roaches treated topically with parathion failed both with bioassay and microanalytical tests. Roan *et al.* (1950) also failed to find any indication of radioactive P^{32} in the central nervous system of roaches treated with tetraethyl pyrophosphate tagged with P^{32}.

It appears from these results, that parathion is absorbed from surrounding tissues into the central nervous system, where it may be metabolized. This breakdown makes parathion *per se* undetectable in nerve tissue. Hartley & Kilby (1950) report that the enzyme chymotripsin may tie up the acid portion of the parathion molecule, thus releasing nitrophenol. This would account for the failure to detect parathion in nerve tissue and supply further evidence to support the idea that the material is metabolized *in vivo*.

SUMMARY.—(1) Sectioning of the ventral nerve cord at various intervals of time following treatment with parathion indicated that the ventral nerve cord was

involved in the transport of parathion, and that the knockdown time decreased as the time between treatment and nerve tissue removal increased.

(2) The relative capacity of several tissues in the American roach to absorb parathion *in vivo* following topical applications were determined microanalytically.

(3) Parabiotic connections between two roaches were made with the blood as the only tissue contact. Parathion applied topically to one insect was detectable in the other roach at knockdown. This gave final proof that the blood was one mechanism for the translocation of parathion.

(4) Both the central nervous system and the blood were active in translocating parathion in the insect body. The ventral nerve cord remained more effective in translocating the toxic principle of parathion, probably some toxic metabolite. Such metabolites may be the toxic agents which cause the death of insects. The blood assumed a secondary role in translocation.

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Timing Treatments for European Corn Borer Control

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The generally accepted European corn borer treatment schedule was devised by Batchelder, *et al.* (1937). Derris, nocotine, or phenothiazine was applied four or five times at 5-day intervals beginning when eggs began to hatch. Pepper & Carruth (1945) applied DDT and *Ryania* insecticides according to the same schedule.

Attempts to vary this schedule by reducing the number of treatments, lengthening intervals, or starting at other times (Britton, *et al.* Turner 1939, Turner 1940, Beard & Turner 1942, Pepper & Carruth 1945) produced no schedule as satisfactory as the standard. Hawkins and Thurston (1949), working in a one-generation area, reported that control in plots which were dusted once with *Ryania* on July 31, and plots dusted once on August 6 was approximately 40 per cent as compared to 78.8 per cent in plots dusted four times. In later work Hawkins (1951) applied single DDT sprays at five-day intervals. Greatest control was obtained with the later sprays.

EXPERIMENTAL PROCEDURES AND RESULTS.—The experiments reported in this paper were carried out during the 1949 and 1950 growing seasons for the purpose of determining the relationship of corn borer oviposition and the development of the corn plant with the timing of treatments for borer control on sweet corn under Maryland conditions. They were applied with the particular view of working out the most effective time for the application of a single spray. Three plantings of corn were made each year: early, mid-season, and late. The late planting in 1950 did not mature. Oviposition counts were made frequently on all plantings.

Single application of DDT spray were made on a series of duplicate plots of each planting, the first being applied when the plants were in the whorl stage. Successive sets of duplicate plots of each planting were treated thereafter at intervals of seven to ten days. No plot received more than a single spraying. Plots were four

Table 1.—Results of single applications of wettable DDT suspension at different periods for European corn borer control on early Marcross sweet corn.

DATE OF TREATMENT	PLANT MATURITY	PER CENT STALKS INFESTED	NO. BORERS PER 100 STALKS	PER CENT REDUCTION OF BORERS IN STALKS	PER CENT EARS INFESTED	PER CENT REDUCTION OF INFESTED EARS
			1949			
June 14	Whorl, 10 to 20 inches	22.0	30.5	37.5	5.2	3.7
June 21	Full tassel	29.5	44.5	8.8	5.2	3.7
June 28	Full silk	34.5	41.0	16.0	3.2	40.7
July 4	Silk drying	27.0	51.0	—	3.0	44.4
Control A	———	36.5	52.0	—	7.7	—
Control B	———	25.5	45.5	—	2.6	—
			1950			
June 26	Late whorl, 2 ft.	9.5	4.5	70.0	0	100.0
July 3	Full tassel	7.5	5.0	66.7	0	100.0
July 10	50% silk	6.5	5.5	63.3	0.5	44.4
July 17	Silk drying	8.0	7.5	50.0	1.0	—
Control	———	14.5	15.0	—	0.9	—

rows wide, but records were taken only on the two inside rows. Infestation records were made separately on ears and stalks at harvest time.

A high Volume spray consisting of 2 pounds 50 per cent wettable DDT powder per 100 gallons was used for all treatments. It was applied at a pressure of 400 pounds per square inch at the rate of 200 gallons per acre. Three potato type nozzles with No. 3 discs per row were used. This is generally regarded as the most effective method of application.

EARLY PLANTINGS.—The early planting both years was of the Marcross variety. In 1949 this planting was made on April 27, and in 1950 on May 10. Because this variety matures quickly, treatments were applied to only four sets of plots. Ears were harvested in 1949 on July 13 and 14, and in 1950 on July 26 to 28. In 1949 the number of egg masses was highest early in the season and gradually decreased. The greatest number seen at a single examination was 19 per 100 plants and the average was 6.2 per 100 plants per examination. In 1950 the highest number was four per 100 and the average was 0.7 per examination. Egg masses were found only twice, with a 2-week interval between the two occasions. In 1949 the earliest spray, applied during the whorl stage, gave the best control of the borer in the stalk. Sprays during the silk stage gave the best control in the ears. In 1950 all the sprays gave more than 50 per cent control against a rather low borer population in the stalks. The 1950 ear

Table 2.—Results of single applications of wettable DDT suspension at different periods for control of European corn borer on mid-season Golden Cross Bantam sweet corn.

DATE OF TREATMENT	PLANT MATURITY	PER CENT STALKS INFESTED	NO BORERS PER 100 STALKS	PER CENT REDUCTION OF BORERS IN STALKS	PER CENT EARS INFESTED	PER CENT REDUCTION OF INFESTED EARS
			1949			
July 14	Whorl, 20 inch	19.5	23.0	66.9	4.7	40.5
July 21	Early tassel	11.5	18.5	73.4	2.8	64.6
July 28	First silk	15.0	17.0	75.5	2.0	74.7
Aug. 4	Full silk	8.0	9.0	87.0	0.8	89.9
Aug. 11	Silk drying	23.5	34.5	50.3	5.7	27.8
Control	———	36.0	69.5	—	7.9	—
			1950			
July 31	Whorl, 3 ft.	20.5	24.5	19.7	8.6	38.6
Aug. 7	Early tassel	16.0	17.5	42.6	5.6	60.0
Aug. 14	Early silk	11.5	8.0	73.8	1.1	92.1
Aug. 21	Almost full silk	19.5	21.0	31.1	8.5	39.3
Aug. 28	Silk wilting	25.0	31.0	—	12.1	12.9
Control	———	29.0	30.5	—	14.0	—

Table 3.—Results of single applications of wettable DDT suspension at different periods for control of European corn borer on late Evergreen sweet corn, 1949.

Date of Treatment	Plant Maturity	Per Cent Infested Plants	No. Borers per 100 Plants	Per Cent Reduction of Borers in Stalks	Per Cent Ears Infested	Per Cent Reduction of Infested Ears
Aug. 9	Whorl, 24 inch	9.5	14.0	—	0.8	—
Aug. 19	Pre-tassel, 4 ft.	10.0	12.7	2.3	0.7	—
Aug. 27	First silk	4.0	4.5	65.4	0.3	40.0
Sept. 5	Full silk	8.0	13.5	—	0.9	—
Control	———	11.5	13.0	—	0.5	—

population was too low to give any real indication of the value of the sprays. Results are given in table 1.

MID-SEASON PLANTINGS.—The variety used for the mid-season planting in both years was Golden Cross Bantam. The 1949 planting was made on June 10, and the 1950 on June 19. Ears were harvested in 1949 on August 15 and 16 and in 1950 on September 4 to 6. In 1949 the highest egg mass count was 9 per 100 plants and the average was 1.7. No egg mass was found before the silk stage. In 1950 the highest was two per 100 and the average was 0.6. Egg masses appeared only before silking. Since Golden Cross matures more slowly than Marcross, five sets of plots were sprayed. Very promising control was obtained. In 1949, the application at full silk gave the greatest reduction of borers in ears and stalks. In 1950 the spray at the early silk stage gave the most reduction. Results are given in table 2.

LATE PLANTING.—An experiment with late planted corn was carried to completion in 1949. A long-season variety, Evergreen, was planted on July 9. Four sets of plots were sprayed at intervals of approximately ten days. Ears were harvested on September 26 and 27. The highest egg mass count was four per 100 plants. The average was 1.1 per 100 plants per examination. While the borer population was low, the results were similar to those on earlier plantings, the most effective treatment being at the time the first silks were appearing in the field. Results are shown in table 3.

SUMMARY.—These experiments were carried out to determine the most effective time for single spray treatments with relation to the development of the corn plant and the time and rate of oviposition. A wettable DDT high volume spray was used. Applications were made at intervals on early, mid-season, and late plantings of sweet corn.

On all plantings there appeared to be a definite relationship between development of the corn plant and best time of treatment. Highest reductions of larvae in ears with a single spray were generally obtained during the early silk stage. There was no apparent relationship between rate of time of heaviest egg deposition and effectiveness of treatments at the comparatively low levels of infestation prevailing. The most effective time of treatment was sometimes before heaviest oviposition, sometimes after.

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Corn Earworm Control Experiments in Pennsylvania in 1950[1]

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Damage to sweet corn in Pennsylvania by the corn earworm. *Heliothis armigera* Hubn. has been extensive in the past several years. This has been because of milder winters recently experienced which allowed the earworm to survive the winter and emerge in the spring, and a large increase in acreages of sweet corn in the southeastern part of the state. Mineral oil injection treatments and applications of a 5 per cent DDT dust were and are commonly used by the farmers but generally the treatments are unsatisfactory. Trials with these and other newer material were begun in 1949 and continued in 1950 on a larger scale. The trials performed in 1950 are reported in this paper.

MATERIALS AND FORMULATIONS.—Seven different insecticides were used in these tests, most of them made up into several different formulations and concentrations. The insecticides used were DDT,[2] TDE,[3] 1,1-bis (p-ethylphenyl)-2,2-dichloro-ethane,[3] parathion,[2] methoxychlor,[4] *Ryania*,[5] and dichloroethyl ether. Standard commercial formulations were used throughout with the exception of the *Q-137* dusts, emulsion-mineral oil sprays, and mineral oil injection solution. The *Q-137* dusts were mixed from a 50 per cent dust concentrate and pyrophyllite clay. The emulsion-mineral oil sprays and mineral oil injection solutions were compounded from commercial 25 per cent emulsion concentrates and pure mineral of a viscosity of from 80 to 90 seconds Saybolt.[6] The formulations of these insecticides were dusts, sprays of wettable powders, emulsion sprays, mineral oil and an insecticide combined spray, and mineral oil injection solutions.

METHODS.—Three series of tests of insecticides were run in sweet corn of Iroquois variety in southeastern Pennsylvania. These tests were in separate plantings which matured at different times in the season. The first planting in which tests were run was harvested August 29, the second September 14, and the third September 22. Tests in the first two plantings consisted of four replicates of 50 ears each while the third was of three replicates of 50 ears each.

Every replicate was made up of a double row 35 to 40 feet in length with the material applied on both sides of each row in an effort to simulate commercial conditions. The dusts were applied in all tests at the rate of 40 pounds per acre with a rotary hand duster. The sprays and emulsion sprays were applied with an ordinary knap sack sprayer at the rate of about 50 gallons per acre with the pressure kept at 40 pounds with frequent pumping. The injected materials were applied with a plunger oil can calibrated to deliver 0.5 cc. of insecticide-bearing oil to each ear.

In the first trial three applications of dusts were put on at two day intervals beginning 9 days after the first silks appeared. Emulsion sprays were applied twice, the first application made 9 days after silks appeared and the second 4 days later. The second trial consisted of injections only and these were put on 4 days after the field was in full silk.

The timing of applications in the third test roughly followed the foregoing except that in the case of dusts the first application was made earlier than in the first test, 7 days after the first silks appeared. The delay between the first and second applications of dusts was due to a heavy rain, so that there was a 3-day interval between the first and second applications of dusts, and the intended 2-day interval between the remaining three applications. The emulsions were applied at 3-day intervals beginning 8 days after the first silks appeared, with a total of three applications being made. The wettable powders were applied according to the same schedule as the emulsion sprays. The mineral oil and insecticide emulsion sprays were applied at 4-day intervals beginning 8 days after silks appeared. The mineral oil injections were made 13 days after the first

[1] Authorized for publication on December 13, 1950 as paper No. 1642 in the journal series of the Pennsylvania Agricultural Experiment Station.

[2] Supplied by the Niagara Sprayer Co., Middleport, N. Y.

[3] *Q-137*. Supplied by the Rohm and Haas Co., Philadelphia, Pa.

[4] Supplied by the E. I. duPont de Nemours & Co., Wilmington, Del.

[5] Supplied by the U.S. Industrial Chemicals, Inc., Baltimore, Md.

[6] Atlantic Rfg. Co. "Ultrol 8."

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Table 1.—Corn earworm control with dusts and water emulsions. First silks August 8, harvest August 29.

Material Used	Dates of Application	Clean Ears	Marketable Ears
Dusts:	August 17, 19, 21		
5% DDT		59%	84%
5% TDE		53	77
1% Parathion		52	73
7% *Q-137*		38	73
Water emulsions:	August 17, 21		
2% DDT		71	86
1.5% *Q-137*		65	88
2% TDE		61	90
Check		30	70

silks appeared, or 5 days after the field reached full silk.

At harvest time the ears were examined by slitting the husk with a knife while in place on the stalk and the extent of the damage recorded as well as the species found in the damaged portion. The standards of grading corn were followed in scoring the damage and calculating the extent of the damage. Those ears completely free of damage were scored as clean or as conforming with the grade of U.S. Fancy. Ears which were damaged to the extent of 1.5 inches or less were scored as marketable or in the grade of U.S. No. 1. Any ears damaged to an extent greater than 1.5 inches were considered unmarketable.

The species involved in the damaged ears were recorded to find out to what extent other species of insects attacking ears of corn were responsible for the damage. Infestations by the fall armyworm, *Laphygma frugiperda*, and the corn borer, *Pyrausta nubilalis*, were very light in these plantings and had little influence on the grading of the corn from the treatment plots. For the purposes of this paper, then, only damage done by the corn earworm has been included in the tables.

Results—In table 1 are shown the treatments and results of the first trial where four dust treatments are applied three times at 2-day intervals, and three emulsion sprays are applied twice with a 4-day interval.

Table 3 presents the results of several different formulations and timings of applications in a field severely infested with earworm. This later corn is typical of sweet corn fields in general in southeastern Pennsylvania at this time of season. It was for this reason that the large number of treatments were made in this particular field. All materials applied were significantly better than the check plot. Emulsion sprays of mineral oil and an insecticide were superior to any other type of formulation treated as a group. The other types of formulations tested were relatively effective in this order: water emulsions, mineral oil injections, dusts, and wettable powders.

Table 2.—Corn earworm control with insecticides in mineral oil injected at rate of 0.5 cc. per ear. Applications made August 31, field in full silk August 27, harvested September 14.

Material	Clean Ears	Marketable Ears
1% DDT	81%	95%
1% Methoxychlor	29	73
1% *Q-137*	22	59
1% TDE	20	61
Check	0.5	44

Discussion—The mineral oil and insecticide emulsions tested in the third planting were very satisfactory. The number of clean ears in these test plots was very high regardless of the kind of insecticide used. A 2 per cent DDT treatment was much higher in number of clean ears than the second best material, 2 per cent TDE. The number of marketable ears, however, was high with all materials used.

Water emulsions of the insecticides under consideration were not too satis-

Table 3.—Corn earworm control with various insecticides and formulations; the field showed silks August 25, was harvested September 22.

Material	Dates of Application	Clean Ears	Marketable Ears
Mineral oil emulsions	Sept. 2, 6		
2% DDT+7.5% mineral oil		86%	95%
2% TDE+7.5% mineral oil		77	95
2% Methoxychlor+7.5% mineral oil		73	92
2% *Q-137*+7.5% mineral oil		56	85
Water emulsions	Sept. 2, 5, 8		
2% TDE emulsion		74	92
2% DDT emulsion		60	86
2% *Q-137* emulsion		52	83
Mineral oil injections	Sept. 7		
1% TDE+mineral oil		62	87
1% DDT+mineral oil		55	91
2% Dichloroethylether +mineral oil		48	89
1% *Q-137*+mineral oil		45	83
Dusts	Sept. 1, 4, 6, 8		
5% DDT		77	93
5% TDE		43	81
1% Parathion		39	77
7% *Q-137*		33	78
15% Ryania+0.5% cyclonene		16	89
15% Ryania+0.5% 469		13	61
Wettable powders	Sept. 2, 5, 8		
Parathion 3 lbs./100 gals.		42	80
Q-137 3 lbs./100 gals.		32	79
Check		8	55

factory generally, although a 2 per cent TDE emulsion gave a satisfactory number of marketable ears. There seemed to be no difference in results between two and three applications of the material.

The mineral oil injection treatments in the two different plantings varied widely in their effectiveness. The time of application was about the same in both plantings with regard to the maturity of the corn, so that some other factor must have been responsible for such a difference. The 1 per cent DDT in mineral oil was the best of those tested in the second planting but was surpassed by a 1 per cent TDE mineral oil injection in the third.

On the whole dusts were unsatisfactory, both from the standpoint of control obtained and from the number of applications necessary to obtain reasonable control at two-day intervals were not satisfactory, even in terms of marketable corn. Four applications at two-day intervals were fairly good but approach the point where it is not economically feasible to control the earworm. A 5 per cent DDT dust was the only one tested which proved to be of value at the rate of four applications.

Only two wettable powders were tested and the results were not satisfactory. The evidence is not sufficient to attribute the poor results to either the materials, the formulation, or the concentration.

SUMMARY—Seven different insecticides were used in three plantings of sweet corn in southeastern Pennsylvania. The tests were replicated three and four times with all materials applied by hand equipment. Ears were examined at harvest time and scored as to damage by the corn earworm. The amount of damage was recorded as clean or marketable. Based on the amount of clean corn, the emulsion sprays of mineral oil and an emulsifiable insecticide were the best tested. Of these sprays, a 2 per cent DDT emulsion in 7.5 per cent mineral oil was the most satisfactory.

Importance of Time of Application of DDT Sprays in Control of European Corn Borer

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Preliminary studies on the European corn borer in Maine indicate that the time of application is an important factor in controlling the European corn borer by the use of insecticides. With the objective of reducing the cost of European corn borer control, the field experiments with insecticides carried on continuously since 1946 were revised in 1950. An increase in the efficiency of the treatments through more accurate timing was undertaken. Standard procedure was followed in conducting the experiment except that more than the usual recommended amounts of spray per acre was applied. This was deemed necessary in order to secure satisfactory run-off at the base of the plants.

The results obtained from the use of the DDT sprays are shown in table 1.

RESULTS OBTAINED FROM SINGLE APPLICATIONS OF DDT SPRAY.—Statistical analysis of the data obtained from the plots receiving single treatments of DDT show that, at the 1 per cent level, the treatments produced significant results in control, as compared with the untreated check plots. Control obtained in the plots treated on July 24, 29, and August 3 did not differ significantly from each other, at the 5 per cent level. However, among the single applications there was a sig-

Table 1.—Control of the European corn borer obtained from the application of DDT sprays.

No.	APPLICATION DATES	CONTROL
1	July 19	65.5
1	July 24	80.7
1	July 29	82.8
1	August 3	85.8
2	July 19, 24	76.1
2	July 24, 29	85.3
2	July 29, August 3	86.3
2	August 3, 8	91.9
3	July 19, 24, 29	88.9
3	July 24, 29, August 3	92.2
3	July 29, August 3, 8	93.8

[1] The help of J. J. Devitt and Lawrence Potter, who have been responsible for much of the detailed field work in connection with this project, is gratefully acknowledged.
EASTERN BRANCH PROGRAM, 1950.

nificant increase in the control obtained in the treatment applied on July 24 or later over the treatment made on July 19.

CONTROL IN RELATION TO THE PERCENTAGE OF EGGS HATCHED.—Each year since 1946 a low percentage of control of the European corn borer has resulted when less than 5 per cent of the eggs had hatched at the time of the first application of insecticide. Several years' data on moth emergence, oviposition, and egg hatching indicate the date of 5 per cent level of hatching to be between July 19 and 20. Consequently the first single application of DDT spray was made on July 19. This application resulted in 65.5 per cent control of the European corn borer (Fig. 1). At the time of this application 4.0 per cent of the eggs had hatched. When the single application was delayed until July 24, a control of 80.7 per cent of the borers was obtained; on this date 13.7 per cent of the eggs on the plots had hatched. The increase in control obtained by applying the spray on July 24 was 15.2 per cent. An application on July 29 gave a control of 82.8 per cent which was an increase of 17.3 per cent over the application on July 19. Control of 85.3 per cent of the borers obtained by a spray application made on August 3 was the highest for the single application series. On August 3, 52.0 per cent of the eggs had hatched.

Figure 1 also shows that the percentage of control increased noticeably when the single application was delayed until July 24 and slightly for the two later dates of July 29 and August 3. It can also be seen that after the percentage of hatch reaches about 13 per cent the increase in control is not as rapid as is the rise in the percentage of eggs hatched.

For practical purposes during 1950, July 19 was a little too early for obtaining the best results of single applications of DDT although about 80 per cent control was obtained by waiting until after July 24 when more than 13 per cent of the European corn borer eggs have hatched.

MOTH EMERGENCE AS A BASIS FOR TIMING THE APPLICATION OF INSECTICIDES.—There is no doubt that the discovery of eggs or newly hatched larvae on the corn can be used as a basis for timing the application of European corn borer insecticides. Nevertheless, growers of Maine sweet corn have generally failed to use these natural events effectively only to discover later that corn borer damage was in such an advanced stage that insecticidal control was then impossible.

Methods of timing the application of European corn borer insecticides was the subject of a Maine study in 1948 (Hawkins & Thurston 1949). In 1950 replicated plots were established for further investigation of the effect of timing of single applications of DDT sprays. Study of the data obtained indicate (Fig. 2) that as the cumulative percentage of moth emergence reaches 87 per cent, the chances are good, with other factors being equal, that 80 per cent control can be obtained by a single application of DDT spray and that there may be a slight increase in control up to 99 per cent emergence.

Considering the data in figure 2, it may be concluded that for practical purposes when the moth emergence curve rises steadily to about 87 per cent and then levels off, then is the time when a single application of insecticide can be expected to be most effective. This conclusion also is generally substantiated by data secured during 1948 and 1949.

Ordinarily, abundant rainfall might be

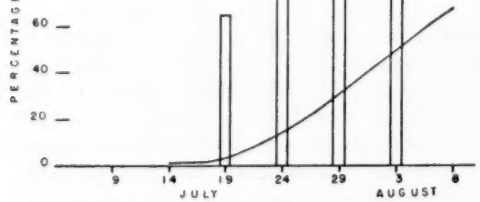

FIG. 1.—The relation between percentage of hatching of the eggs of the European corn borer and effectiveness of single applications of DDT sprays.

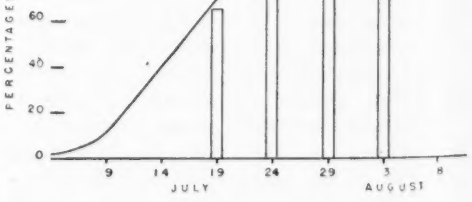

FIG. 2.—The relation between the percentage of moth emergence of the European corn borer and the effectiveness of single applications of DDT sprays.

a factor which would greatly affect the efficiency of the insecticide applied. During the 1950 season the total of 1.64 inches of rain which fell from July 14 to August 8 apparently did not greatly affect the results obtained from the DDT sprays.

Table 2.—Analysis of corn samples for residues on corn with single applications of spray.[1]

DATE	DDT
July 19	0.39 ppm.
July 24	0.91
July 29	2.10
August 3	2.10

[1] Analysis by A. Stanley Getchell, Chemist, Maine Agr. Expt. Sta., November 1950.

The greater portion of this rainfall occurred at the end of this period and probably had more effect on the last spray than on the other single applications.

GROWTH STAGES OF CORN IN RELATION TO CONTROL.—Another factor which might enter into the effectiveness of European corn borer insecticides is that of corn growth stages. This subject has been discussed by Batchelder 1949 and Beard 1943, among others. Data obtained in Maine during 1949 and 1950 show that in general the chances of borer survival increase until the green tassel and mid-tassel stages are reached. Survival is very low in corn which has not yet attained the late whorl stage. Consequently, it is not generally practical to treat corn in Maine until it has at least reached the late whorl stage and the cumulative percentages of eggs hatching have reached a minimum of 13 per cent.

DDT RESIDUES AND DATA RESULTS.—Percentages of control obtained from single applications of DDT did not greatly vary when they were applied on dates of July 24, 29, and August 3. However, the later dates of application resulted in increased control over that applied on July 19. The spray applied on August 3 would also be of some value as an insecticide for any late infestations of the fall army worm which might occur. Therefore unless it is desirable to keep DDT residues at a minimum the later applications would be preferable to those made at earlier dates. In order to obtain information on this subject an analysis of the corn plants was made from samples collected at harvest time and the results are shown in table 2.

Since the available information leads us to believe that there is no tolerance for DDT residue on plant material to be fed to livestock where milk or meat of such animals is to be used for human consumption, it would be unsafe to use corn with DDT residue for feeding livestock.

SUMMARY.—The data from 1950 indicate that single DDT sprays are 80 per cent or more effective if applied when from 13 per cent to 52 per cent of the eggs of the European corn borer are hatched or when from 87 to 99 per cent of the moths, have emerged. A spray applied on the date when approximately 4 per cent of the eggs had hatched and 71 per cent of the moths had emerged was less satisfactory from the standpoint of control than the later applications. Cumulative moth emergence curves appear to be promising bases for timing insecticide applications for European corn borer control. It is probable that insecticides are not necessary for corn in growth stages previous to the late whorl under central Maine conditions. When corn is in the late whorl, the early, the mid- or late-green tassel stage at the time when the moth emergence has reached more than 87 per cent, single applications of DDT sprays will control from 80 to 85 per cent of the borers present. Additional data are are needed as a basis before sweeping recommendations are made; although the the foregoing conclusions are generally substantiated by experimental data obtained each year since 1946.

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Control of the Clear Lake Gnat in California

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For many years the Clear Lake gnat, *Chaoborus astictopus* D. and S., has been an economic problem to residents along the shores of Clear Lake, California. Research on the biology and habits of this pest has been reported in a series of papers by Lindquist and Deonier (1942, 1943, and 1946). Herms (1941) reported on the abundance and habits of the pest. From 1946 to 1949 studies were conducted periodically at the Corvallis, Oreg., laboratory of the Bureau of Entomology and Plant Quarantine to determine the effectiveness of various new insecticides on the gnat larvae. During the course of this work it was found that TDE (dichlorodiphenyldichloroethane) was highly effective against gnat larvae and was relatively harmless to fish. Two experiments in which TDE was used in two small lakes (Lindquist and Roth 1950) showed that these gnat larvae could be greatly reduced or eliminated in small lakes without undue harm to other aquatic organisms.

After these successful experimental demonstrations, the Board of trustees of the Lake County Mosquito Abatement District made plans for a gnat-control project on Clear Lake. The date for treating the lake was set for mid-September 1949, because at that time of year the larvae are still migrating from the mud into the water each night, it is near the end of the season for adult activity, and the water level in the lake is usually low. It was also believed that there is less likelihood of damaging fish at this time.

The U. S. Coast and Geodetic Survey was asked to determine the volume of water in the lake. The volume of Clear Lake was calculated as 853,624 acre-feet at zero Rumsey gage.[1] The Board also requested State aid in financing the project. The State of California, through the Bureau of Vector Control, made available certain funds to assist the local district. Garth I. Murphy, of the California Division of Fish and Game studied the plankton and fish before and after treatment. J. K. Peterson, a local resident of Lake County, assumed the responsibility for making the arrangements and supervised the application of the insecticide. The Bureau of Entomology and Plant Quarantine provided technical leadership in planning and carrying out the control program.

PLANS FOR THE CONTROL PROGRAM.—The distribution of approximately 14,000 gallons of insecticide over a lake of this size (41,600 acres) required considerable planning and preparation. Aerial application was considered, but it was estimated that the material could be applied at lower cost by surface craft, and there was less likelihood that adverse weather or breakdown of equipment would interrupt the treatment before it was completed. The operation of surface craft required six large tugboats capable of pulling barges loaded with the insecticide.

The large arm of the lake was divided into six sectors each a mile wide, as shown in figure 1.

To prevent the insecticide from concentrating near the shore and possibly injuring littoral fauna, none was to be discharged within .75 mile of the western shore or 0.5 mile from the eastern shore. It was believed that wave action and water currents would rapidly distribute the chemical evenly throughout the water. Four round trips, or eight swaths approximately 700 feet apart were to be made on each sector. The insecticide was to be discharged by gravity flow direct from 50-gallon drums, as shown in figure 2. A discharge rate of one drum in 20 minutes was obtained by laying the barrel on its side and allowing the fluid to run through a 3-foot length of .625-inch plastic hose with a thin metal spout.

The insecticide was prepared by a chemical company according to the following formula: TDE 30 grams, emulsifier, 10 ml., and xylene 72 ml. The amount of insecticide to be dispersed on each sector was determined by calculating the approximate water depth and surface area. The number of drums employed for each swath is given in figure 1. One drum was discharged continuously as the boat was

[1] A gage established to determine water levels.

moving along the swath, but over the deeper areas one or more additional drums were set to discharging, depending on depth.

Markers to establish the boundaries of each sector were set out several days prior to treatment. Some of the courses were marked with a 10 by 10-foot cloth-covered panel attached to a piling driven into the bottom mud. The boundary lines along each course were marked by anchored wooden floats carrying flags that were visible for several hundred feet.

All preparations were completed on September 14. Each boat captain had two assistants to handle drums and discharge the insecticide. Each boat and crew had made practice runs over its respective course and had been briefed on the procedure to be followed. Additional drums in excess of the barge capacity were located at strategic places ready for loading. The fifteenth was clear and calm, and all boats started their runs at 6 A.M. Little difficulty was encountered in the operation. In the afternoon a storm came in, and rather severe wave action impeded progress, but the entire large arm of the lake was treated that day. September 16 was exceedingly stormy and rough, but the crews were able to complete the application on the two lower arms of the lake. It was indeed fortunate that the large arm had been treated the day before, because the storm played havoc with the markers; some broke loose from their moorings and others moved considerable distances. What effect, if any, the strong wave action had on dispersion of the insecticide is not known. At the time it was believed that the upper end might have lost some of the insecticide as the wind piled the water into the narrows and lower areas.

The lake level dropped rapidly during the first half of September. On September 14 the Rumsey gage showed 0.8 foot above zero. The original plan called for treatment at the rate of 1 part of TDE to 75 million parts of water. However, approximately 14,000 gallons of the insecticide were applied, or about 1 part of TDE to 70 million parts of water.

TREATMENT OF SMALLER NEARBY LAKES.—To minimize the chance for reinfestation and build-up of the gnats in Clear Lake, 20 ponds, reservoirs, and small lakes within 15 miles of this lake were treated with TDE during September, October, and November. Eric C. Winkler, entomologist for the Lake County Mosquito Abatement District, performed this work with the assistance of Garth I. Murphy of the California Fish and Game Commission.

DETERMINATION OF EFFECTIVENESS OF THE TREATMENT.—The gnat larvae rise to the surface when they are affected by TDE or other chlorinated hydrocarbon insecticides. One and two days after the treatment sheets of floating larvae were observed extending for miles. At places hundreds of larvae per square foot were concentrated on the water surface. Larvae recently killed or affected by the chemical were seen there as long as 11 days after the treatment.

Since there was a tremendous population of adults along the shore and back in the hills at the time of treatment, oviposition was heavy for at least 5 days. Heavy dark-brown sheets of eggs on the water were observed on the 4th day. The last eggs were seen 7 days after the treatment. Apparently the billions of young gnat larvae hatching from those eggs were killed by the toxicant in the water.

Considerable numbers of adult gnats were observed around lights for 9 evenings, but none were seen after the 13th day. The absence of adult gnats was undoubtedly due in part at least to the treatments, although there is a normal decline in numbers at that time of the year.

TOXICITY OF THE WATER.—An attempt was made to determine how long the water would remain toxic and how well the insecticide dispersed throughout the lake. The first tests were made with gnat larvae collected in Blue Lake and stored in 50-gallon drums containing mud and water. Water samples taken along the shore line from Lakeport to the Narrows, a distance of about 15 miles, were brought to the laboratory and 20 larvae were exposed to each sample. Only a few of the samples killed all the larvae in 24 hours. Water samples collected out in the lake appeared to be much more toxic, a indication that the insecticide dispersed rather slowly towards the shore.

Numerous water samples were collected on the 8th and 11th days after treatment and brought to the Corvallis laboratory for testing against first-stage floodwater *Aedes* larvae. The tests were therefore made several days after the water was

collected. Only two of the samples showed over 60 per cent kill in 48 hours. A known dosage (0.0025 p.p.m. or 1 to 400 million) of the TDE emulsion killed 46 per cent of the mosquito larvae in 48 hours. These bioassay tests therefore indicated that the water in Clear Lake contained for the most part less than 0.0025 p.p.m. of the TDE 10 to 18 days after the treatment. However, it is known from previous laboratory tests that even such low concentrations of TDE will cause rather high mortality of gnat larvae exposed in treated water for several days. Four bottom-mud samples collected after 75 days caused no mortality of mosquito larvae.

A record of considerable interest was made by Robert L. Usinger, associate professor of entomology, University of California, 28 days after the lake had been treated. Two bottom mud samples taken in 20 feet of water about 3 miles out from Lakeport were subjected to colorimetric analysis for TDE. One sample, in which the top layer of mud was analyzed, showed 0.61 p.p.m. of TDE. The other sample, taken by allowing the dredge to sink into the mud, showed a doubtful 0.15 p.p.m. These records indicate that at least some of the insecticide had settled to the bottom mud within 28 days.

EXAMINATION OF BOTTOM SAMPLES.—A series of 40 bottom-mud samples were taken at 20 stations on September 12, three days before treatment. Of these stations 9 were established on a line between Lucerne and Lakeport and 11 on a course running through the Narrows into the Clear Lake Oaks and Clear Lake Highlands arms. On an average 36.15 gnat larvae per sample were counted. This average is smaller than usual for the fall months. Post-treatment checks on hundreds of mud samples made on this line 4, 34, and 208 days after treatment showed 87.5 per cent reduction of gnat larvae on the 4th day and 100 per cent thereafter. The organisms found at each station are given in table 1.

Many samples were taken at other points in the lake. Table 2 gives the organisms found in 360 post-treatment samples taken along several courses extending for approximately 54 miles. Very few gnat larvae were taken 6 to 8 days after treatment, and no larvae were found in samples taken after the 11th day. Extensive surveys taken in other years have shown gnat populations averaging 80 to 150 per sample the first part of October. Many thousands of samples taken previously showed that gnat larvae were always present except in samples taken close to the shore.

These studies suggest that a remarkable degree of control has been achieved. It is recognized, however, that the mud samples taken represent an extremely small

Table 1.—Organisms found in bottom-mud samples before and after treatment of Clear Lake with TDE. Average number of organisms per sample in two Ekman samples taken at each station.

		Before Treatment					4 Days After Treatment[1]			24 Days After Treatment[2]		208 Days After Treatment[3]	
Stations	Sample	*Chaoborus*		*Chironomids*	*Oligochaetes*	Other	*Chaoborus*	*Chironomids*	*Oligochaetes*	*Chironomids*	*Oligochaetes*	*Chironomids*	*Oligochaetes*
		Larvae	*Pupae*										
Course, Lakeport to Lucerne	1	58	1.5	5	7	2.5	9	1	8	0	9	.5	22
	2	42	0	3	12	.5	4	2.5	2	0	11	.5	24
	3	81	5	3	6	0	.5	2	3	0	11	0	40
	4	72	1	6	4	0	2.5	1	11	1	7	0	14
	5	24	.5	8	22	2	4	1	7	0	7	0	19
	6	47	6	10	7	1	14	3	14	0	10	0	16
	7	45	.5	8	15	0	11	2	9	0	7	0	18
	8	42	1.5	11	12	1.5	18	3	2	0	8	.5	14
	9	18	1.5	1	15	3	9	7	12	1	19	0	21
Pepperwood Cove	10[4]	100	0	0	12	6	1.5	2	8	1	12	0	19
Soda Bay	11	80	1	8	27	2	7	4	11	3	11	0	15
Konotayee	12	22	.5	11	31	3	3.5	2	6	3	8	2	14
Buckingham Park	13	50	1	11	14	1	3	3	6	1	17	4	22
Craig Island	14	8	2	6	15	1.5	1	3	8	0	30	1.5	30
Indian Village	15	16	0	6	7	0	.5	3	4	0	16	0	30
Rattlesnake Isle	16	5	1.5	12	18	0	0	3	8	1	20	0	25
Craig Island	17	3	0	8	40	0	1.5	2	10	0	30	.5	26
Applebaum's	18	8	.5	8	36	0	2	5	32	1	18	1.5	24
Pirate's Cove	19	2	0	8	27	0	1	2	24	1	8	1	15
Bead Island	20	10	0	9	28	0	0	3	24	2	22	.5	15
Average per sample		36.2	1.2	6.2	17	1.3	4.5	2.1	10	0.8	14	.6	21.5

[1] No other organisms.
[2] No *Chaoborus* or other organisms.
[3] No *Chaoborus*, 10 other organisms in sample 1, 5 in sample 2, and 1 in sample 3.
[4] Landmarks, bottom samples taken .25 to 0.5 mile from these points.

segment of the huge lake, and that the method of sampling was not adequate to determine whether complete elimination of the larvae had likely been achieved.

EXAMINATION OF WATER SAMPLES.—In order to check further for the presence of gnat larvae remaining in the lake, another sampling method was used. Plankton nets were drawn through the water at night in an effort to take free-swimming larvae that migrate upward from the mud after sunset. Previous checks indicated that this method of sampling, when normal numbers of gnat larvae are present in the lake, could be expected to yield several larvae per cubic foot of water. The first tests were made 33 and 34 days after treatment. Two small nets having a total opening of 1.63 square feet were towed for several miles at various places over the lake, but only two gnat larvae were taken. The amount of water strained was estimated roughly at about 10,000 cubic feet. Sampling of this magnitude would have yielded at least 50,000 larvae in previous years.

After 75 days and again after 210 days, additional samples were taken with two large nets each having an opening of 4 square feet and with one smaller net having an opening of 3 square feet. The nets were of porous cloth so as to capture gnat larvae but readily permit water to pass through. Weights were ataached to the nets so that they could be drawn at predetermined depths. One of the large nets was towed near the bottom of the lake. No *Chaoborus* larvae were taken in either series of samples. Although the exact amount of water passing through the nets was not determined, it is safe to state that it exceeded 100,000 cubic feet in each series. Samplings similar to this but on a much smaller scale in previous years would have yielded several hundred thousand larvae.

The taking of bottom and water samples as a part of this study was terminated on April 15, 1950. However, observations to detect any possible adult activity around lights were made throughout the summer, and suction-type light traps were operated at Lakeport and Lucerne between June 15 and October 14 in a further attempt to determine the incidence of the species. Bottom samples were taken routinely from June 15 to October 20. This survey was conducted mainly by Eric C. Winkler. Neither he nor other observers found any *Chaoborus* gnats at Clear Lake. As far as could be determined not a single specimen of this species was observed or recovered

Table 2.—Organisms found in other parts of Clear Lake at various times after treatment. A total of 360 Ekman samples taken at 150 stations.

COURSE	DAYS AFTER TREATMENT	NUMBER OF SAMPLES	AVERAGE NUMBER OF ORGANISMS PER SAMPLE			
			Chaoborus	*Chironomids*	*Oligochaetes*	Other
Nice to Soda Bay	6	20	2.8	1.7	35.2	0.8
	11	40	0.2	1.3	14.7	0
	34	24	0	0.4	10	0
	209	28	0	0.8	17.3	0
Shag Rock to Rocky Point	34	20	0	0.3	13.6	0
	209	26	0	1.2	26.2	0.1
Rocky Point to Lucerne	8	20	1.4	1.4	24	0
	34	26	0	0.2	18	0
Nice to Tule Point	33	20	0	0.3	11.3	0
Nice to Lucerne	33	10	0	1.8	15.2	0
Soda Bay to Shag Rock	33	6	0	0.1	12	0
Rocky Point to Nice	34	14	0	0.8	12.6	0
Middle of Lake	209	8	0	1.3	20	0
Lower Arms	11	60	0	1.1	16.5	0
	34	28	0	1.1	17.4	0
	209	10	0	1.0	18.7	0

along the shores of Clear Lake. This indicates eradication for at least one season. Bottom samples from several of the small lakes, however, yielded a few *Chaoborus* larvae late in the summer. Because of this, reinfestation of Clear Lake will probably occur in the future. These lakes were promptly retreated with TDE at the rate of approximately 1 part per 60 million.

DISCUSSION.—The control program and results obtained are unusual in entomological endeavors (Knipling 1950). The treatment of a body of water of this large size with an insecticide is in itself an outstanding achievement. The dispersion of the chemical from the 700-foot swaths so that it would cover the area and mix thoroughly with the water is of importance. Wave action and subsurface currents played a large role in the distribution of the insecticide, and it is possible that a glassy calm lake for several days might have prevented good kill of larvae.

Perhaps the basic reason for the successful kill of the species was the larva's habit of nocturnal migration into the upper waters. During the daylight hours the larvae are imbedded in the soft bottom mud, and laboratory experiments had shown that no kill could be obtained unless the larvae migrated. The vertical migration of the larvae was found to be pronounced at water temperatures of 74° to 78° F., but slow and uncertain at water temperatures below 60°. A good knowledge of the habits of the insect made it possible to obtain control with a safe concentration of insecticide at a comparatively small cost.

Another noteworthy feature was the eradication of *Chaoborus* without any apparent injury to other aquatic insects or to fish, plankton, or oligochaetes. At the dosage used the insecticide proved to be almost selective for the species to be controlled.

The destruction of a species as abundant as *Chaoborus astictopus* will probably require adjustments by other species of animals in the lake. Since the lake produced many tons of *Chaoborus* annually, no doubt a state of biological unbalance now exists between the food of the larvae (Rotifera and Copepoda) and the larvae as a food for other organisms. The vacuum produced by elimination of *Chaoborus* may be filled by other species, perhaps by some of the chironomids. All this is conjecture, however, and readjustments of the various species involved may come about without undue harm to them or to man and his activities.

SUMMARY.—The Clear Lake gnat, *Chaoborus astictopus* D. and S., has long been a problem of economic importance in the environs of Clear Lake, California. Laboratory and field studies has indicated that TDE (dichlorodiphenyldichloroethane) was effective in killing larvae of the gnat at concentrations of approximately 1 part of insecticide to 50 to 100 million parts of water. These findings prompted the Lake County Mosquito Abatement District to proceed with a gnat-control project. Approximately 14,000 gallons of a 30 per cent TDE emulsion were dispersed over the 41,600-acre lake by surface craft. The insecticide flowed undiluted from 50 gallon drums through a small tube by gravity flow. The boats made swaths approximately 700 feet apart across the lake, and the entire operation required 2 days.

Hundreds of bottom samples were taken from the lake after the treatment, but no gnat larvae could be found. Nets drawn through the water at night several months after treatment did not capture any free-swimming larvae. No *Chaoborus* adults were found around Clear Lake during the summer of 1950. It appears that complete control of this species was accomplished without any immediate harm to other aquatic organisms.

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The Occurrence of *Gasterophilus* spp. in Texas and Some Tests with Insecticides for Their Control

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During the spring and summer of 1950 the stomachs and duodena of horses slaughtered near San Antonio, Texas, were examined at weekly intervals to study the incidence of *Gasterophilus* spp., or horse bots. Most of the horses came from farms and ranches within 100 miles of San Antonio and few, if any, were shipped as far as 200 miles. In general, the horses were in poor physical condition, due partly to severe bot infestations and partly to old age and other causes.

It was hoped that some of the recently developed insecticides would be highly toxic to horse bots and might be easier to administer than carbon disulphide, the material recommended for horse bot control. Therefore, laboratory tests were conducted with horse bots immersed in chlorinated hydrocarbon and organic phosphate insecticides. Several insecticides were also administered to bot-infested horses to check the correlation between laboratory and *in vivo* tests.

EXTENT OF INFESTATION.—The frequency distribution of the horse bots in 508 stomachs examined between February 16 and August 16 was as follows:

NUMBER OF BOTS PER HORSE	NUMBER OF HORSES	NUMBER OF BOTS PER HORSE	NUMBER OF HORSES
0	3	801–900	4
1–100	176	901–1000	0
101–200	102	1001–1100	2
201–300	85	1101–1200	1
301–400	52	1201–1300	1
401–500	38	1301–1400	0
501–600	26	1401–1500	0
601–700	7	1501–1600	0
701–800	10	1601–1700	1

Only three of the stomachs were free of bots. In the others the number ranged from 1 to 1659, an average of 226 per animal. Five of the stomachs contained more than 1000 bots.

SPECIES FOUND.—Of the three common species of horse bots—*Gasterophilus intestinalis* (Deg.), *G. nasalis* and (L.), and *G. haemorrhoidalis* (L.)—only the first two were found during this study (Table 1). Larvae of *G. intestinalis* were the more abundant (61 per cent). Although most of the animals were infested with both species, nine were infested with *nasalis* only and 51 with *intestinalis* only.

Most of the *Gasterophilus intestinalis* larvae were attached to the pharyngeal lining of the stomach. However, in some of the more heavily infested stomachs a few were attached to the soft lining of the pyloric surface. Any larvae found beyond the pylorus were not firmly attached and appeared to be out of their natural habitat. All the *G. nasalis* larvae were found in the pylorus and the anterior duodenum, except a few that were clinging losely to various portions of the stomach.

The counts of *Gasterophilus nasalis* (Table 1) are slightly lower than the infesta-

Table 1.—Average number of *Gasterophilus* larvae collected per horse. February-August 1950.

MONTH	NUMBER OF STOMACHS EXAMINED	*G. intestinalis*		*G. nasalis*	
		Second Instar	Third Instar	Second Instar	Third Instar
Feb.	54	23	112	4	86
Mar.	69	24	106	7	82
Apr.	70	7	97	11	37
May	73	9	168	33	80
June	105	17	134	44	48
July	79	18	105	24	74
Aug.	58	15	124	10	73

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tion that actually existed. In the butchering process some of the stomachs were severed from the intestine at the pylorus, and the duodena were not available for examination.

Among the third-instar larvae collected from the pharyngeal portions of the stomachs, six were found that differed from typical *Gasterophilus intestinalis* larvae in arrangement of the spines and other characteristics. E. F. Knipling, of this Bureau stated that these larvae were not one of the three common species of *Gasterophilus* and that further study would be necessary before the species could be determined.

SEASONAL ABUNDANCE.—There was little change in the average number of bots per horse as the season progressed, and there was no change in the proportion of one species to the other. Table 1 shows that the proportion of second- to third-instar larvae of *Gasterophilus intestinalis* did not change greatly at any time between February and August and that in the vicinity of San Antonio the horses become infested at all seasons of the year. It is well known that larvae of this species will remain viable in the eggs for several weeks. Although the adults tend to be inactive during the winter, the horses are subject to infestation from such viable eggs on the hairs of the host.

There was a marked increase in the number of second-instar larvae of *Gasterophilus nasalis* each month from February until June, after which they decreased in number. In February the ratio of third to second instars was approximately 20 to 1, but in May this ratio decreased to 2.4 to 1. This trend reached a peak in June, when the second instars decreased in number until the day of the last collection in August. On that date the ratio of third to second instars was almost 20 to 1. Apparently this species is affected by seasonal changes in weather, and at San Antonio the adults reach a peak of abundance and activity in the spring.

TESTS WITH INSECTICIDES.—In preliminary laboratory tests 10 third-instar larvae of *Gasterophilus intestinalis* were immersed in an acetone solution containing 5 per cent insecticide and 10 per cent of a solvent[1] for 1 hour and then transferred to a 0.25-per cent solution of hydrochloric acid and held at 38° C. The insecticides tested and the larval mortalities obtained after 24 and 48 hours were as follows:

INSECTICIDE	LARVAE DEAD AFTER	
	24 Hours	48 Hours
Dieldrin	1	3
Aldrin	0	0
Heptachlor	2	3
DDT	0	1
Methoxychlor	1	1
TDE	3	3
Benzene hexachloride	6	6
Toxaphene	3	6
Chlordane	3	8
Parathion	1	5

For the *in vivo* tests all the chemicals shown in table 2 were administered to horses by veterinarians.[2] A stomach tube was used to place the materials, except lead arsenate, in the stomach. The lead arsenate was mixed in the horses' feed. One horse was used for each treatment. Four horses were not starved prior to treatment, but after the stomach of one of these horses had been examined, it was decided that the results would be more uniform if feed was withheld until the stomachs became empty. Therefore, this procedure was followed in the treatment of the other 10 horses.

The solids, other than lead arsenate, were in the form of wettable powders and were suspended in water. The liquids were administered undiluted or as emulsions.

Three to 6 days after treatment the horses were slaughtered and the stomachs examined immediately. The number of larvae that had been expelled as a result of the treatment was obtained by counting the attached and unattached bots in the stomach and the duodenum, and also the characteristic ulcers. The deeply pitted lesions caused by the attachment of the larvae in the pharyngeal portion of the stomach healed slowly and could be counted easily 6 days after treatment. The soft lining of the duodenum appeared to heal much faster, however, and the lesions caused by *Gasterophilus nasalis* were difficult to count after 6 days had elapsed.

The results of these tests, given in table

[1] A sorbitan monolaurate polyoxyalkyline derivative.

[2] The help and cooperation of R. D. Radeleff and W. J. Nickerson, of the Bureau of Animal Industry, with this phase of the investigation is gratefully acknowledged.

Table 2.—Number of *Gasterophilus* larvae expelled from or remaining in horses' stomachs as a result of various insecticide treatments administered orally. Stomach empty except when indicated otherwise.

		G. intestinalis			*G. nasalis*		
			Present			Present	
INSECTICIDE	DOSAGE	Expelled	Second Instar	Third Instar	Expelled	Second Instar	Third Instar
	mg./kg.						
Lindane[1]	50[2]	0	7	61	0	0	89
Lindane	25	0	0	121	0	0	23
Dieldrin[1]	25	0	9	120	0	0	50
Aldrin[1]	25	0	1	132	0	0	13
Heptachlor	100	0	0	66	0	0	4
Chlordane	45 (approx.)	0	0	107	0	0	41
Lead arsenate[1]	5	0	0	228	0	0	95
Lead arsenate	5	0	0	219	0	0	34
	cc./100 lb.						
Toluene:[3]							
Undiluted	20	48	0	1	0	0	3
Emulsion	20[4]	147	0	0	112	0	1
Distilled pine oil:							
Undiluted	20	0	3	395	0	12	4
Emulsion	20[4]	0	0	119	0	22	27
Carbon disulfide:							
Undiluted	2.5	193	3	0	100	0	0
Suspension	2.5	27	2	0	200	0	0

[1] Stomach full.
[2] Horse died 3 hours 10 minutes after treatment.
[3] Not considered an insecticide, but has recently been used for effective bot control.
[4] Dosage calculated on basis of actual toxicant.

2, show that lindane, dieldrin, aldrin, heptachlor, chlordane, lead arsenate, and pine oil were completely ineffective. Toluene, reported by Todd *et al.* (1950) as being effective for horse bot control, was found to remove bots from two horses when used at the higher dosage mentioned by them 20 cc. per 100 pounds of body weight. Incidental to these counts, it was noticed that there was sever sloughing of the lining of the stomach when carbon disulfide was used, whereas the stomachs of the horses treated with toluene appeared more nearly normal.

SUMMARY.—An examination of 508 horse stomachs from February to August 1950 revealed that most of the horses in the vicinity of San Antonio, Texas, are infested with the larvae of *Gasterophilus intestinalis* (Deg.) or *G. nasalis* (L.). Only three horses were bot-free, one horse was infested with 1659 larvae, and the average number of larvae was 226 per horse.

In laboratory tests third-instar larvae of *Gasterophilus intestinalis* were found to be extremely resistant to dieldrin, aldrin, heptachlor, DDT, methoxychlor, TDE, benzene hexachloride, toxaphene, chlordane, and parathion. This observation was varified when infested horses were treated with dieldrin, aldrin, heptachlor, chlordane, and lead arsenate. Toluene at 20 cc. per 100 pounds of body weight freed two horses of their bots.

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Effect of Rainfall and Other Factors on the Toxicity of Certain Insecticides[1]

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Continued investigations are being made at this Station relative to the factors affecting the toxicity of certain insecticides. Results of the work conducted during 1948 and 1949 have been reported by Gaines & Dean (1949, 1950). It was found that laboratory-reared weevils were more susceptible to the organic insecticides than were the field collected weevils. High temperatures and humidities have proven to be important factors in reducing the toxicity of several organic insecticides. In general, the emulsifiable sprays have been found to be more toxic than the dust formulations. Exposing the treated plants to sunshine and simulated dews, also has proven to be important in reducing the toxicity of all the insecticides used. Exposure to sunshine and dew reduced the toxicity of the dusts more than the sprays. From the results of these tests, it was observed that weevils were more susceptible to poisons during the early growing season than they were during the latter part of the summer. Rainwater & Gaines (1951) have summarized results of a large number of tests showing that there were factors other than environmental, which affected the toxicity of certain insecticides, during the season.

The tests herein reported were conducted at College Station during 1950 to obtain additional information regarding the effect of environmental factors on the toxicity of certain organic insecticides. Most of the tests were designed to determine the effect of rainfall in the toxicity of both spray and dust formulations of certain insecticides, for the control of boll weevil, *Anthonomus grandis*, Boh., leafworm, *Alabama argillacea* (Hbn.), and salt-marsh caterpillar, *Estigmene acrea* (Dr.). Two new compounds, aldrin and dieldrin, were included for comparisons with toxaphene.

The methods used in making these tests have been described in the papers referred to above. The percentage mortalities were calculated by Abbott's formula and the dosage-mortality curves were calculated by Bliss' method. Check or untreated weevils were included in all tests.

Hygrothermographs were used to record the temperature and relative humidity through the duration of each experiment.

The sprays were made by diluting miscible oil concentrates with water. The dosages are shown as pounds active ingredients per acre.

Experiment 1, table1, was conducted to determine the difference in the toxicity of toxaphene, dieldrin and aldrin when applied as sprays and dusts for boll weevil control. The tests were conducted in the laboratory, greenhouse and the field during the period of August 11 to August 31 for the purpose of obtaining information relative to the factors which might effect the toxicity of the insecticides. Comparable samples of field-collected weevils were used in all tests. The average daily temperatures in the laboratory, during the test period, ranged from 79.1 to 91.6° F. and the average daily relative humidities ranged from 39.5 to 80.4 per cent. The average daily temperatures in the greenhouse, which was shaded from sunshine during the test period, ranged from 77.5 to 96.5° F. and the average daily relative humidities ranged from 46.4 to 86.7

Table 1.—Results of cage toxicity tests for boll weevil control conducted in the laboratory, greenhouse and field using insecticides indicated applied as sprays and dusts in Experiment 1 at College Station, Texas.

Treatment	Laboratory		Greenhouse		Field	
	Dose[1]	Per Cent Mortality[2]	Dose[1]	Per Cent Mortality[2]	Dose[1]	Per Cent Mortality[2]
Toxaphene						
Dust	.45	29.9	.36	52.0		
Spray	.102	35.7	.12	48.9	1.14	31.9
Dieldrin						
Dust	.045	53.7	.045	50.3		
Spray	.016	57.6	.016	60.2	.204	38.7
Aldrin						
Dust	.172	32.2	.144	51.4		
Spray	.064	48.8	.064	53.2	.539	16.4

[1] Pounds active ingredient per acre. An average of 5 dosages in the laboratory and greenhouse and 7 in the field.

[2] Average percentage mortality of 4 replicates of each of the 5 dosages in the laboratory and greenhouse and 3 replicates of each of the 7 dosages in the field.

[1] Technical contribution No. 1465, Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. Thanks are due Messrs. H. A. Dean, J. W. Selby and M. E. Merkl for assistance in conducting some of the tests.

per cent. In the field, the average daily temperatures ranged from 71.0 to 95.4° F. and the average daily humidities ranged from 38.7 to 92.9 per cent.

The sprays in the laboratory and greenhouse were applied to either potted cotton plants or tops of cut-plants. Two hollow cone nozzles were used for dispensing the spray at the rate of approximately 5 gallons per acre. The plants were rotated through this spray. In the field cage tests, the sprays were applied to each plant which was individually enclosed in a cylinder. A solid cone nozzle dispensing about 7.5 gallons of spray per acre was used. The dusts were applied in all cases to each plant which was enclosed in a cylinder. The same air pressure was used to blast the dust into the top of the cylinder. The live and dead weevils were recorded in the laboratory and greenhouse at the end of a 3-day period and in the field at the end of 5 days.

The spray formulations of toxaphene, aldrin and dieldrin proved to be more effective in the laboratory and greenhouse than did the dust formulations. Little difference was noted in the toxicity of these three compounds in the laboratory as compared to the greenhouse. The maximum temperatures in the greenhouse were considered sufficiently high to affect the toxicity of either of the three insecticides, and they were not greatly different from the laboratory temperatures. Under the conditions of high temperatures, the toxicity of certain insecticides was reduced. The temperatures were considerably lower during the test period this year in the greenhouse than in previous years. Considerably higher dosages of the insecticides were necessary to give a kill in the field comparable to that in either the laboratory or greenhouse. Since the temperatures did not vary much in the laboratory, greenhouse, or field, it is assumed that the wider range in percentage relative humidity, sunshine, wind, dew, or the combination of these factors brought of about a decided reduction in the toxicity of toxaphene, dieldrin and aldrin. These climatic factors reduced the toxicity of aldrin more than that of either dieldrin or toxaphene.

Dieldrin proved to be more toxic to the boll weevil than either aldrin or toxaphene.

Experiment 2, table 2, was designed to determine the effect of simulated rain on the toxicity of toxaphene, dieldrin and aldrin sprays when used for the control of boll weevils. The tests were conducted in the laboratory using field-collected weevils. The average daily temperatures in the laboratory during the period September 20 to October 18 ranged from 73.4 to 84.9° F. and the average daily humidities ranged from 42.3 to 73.3 per cent. The sprays were applied with the apparatus aforementioned which rotated the potted plants through the spray dispersed through hollow cone nozzles. Potted cotton plants were treated with each spray in each of 4 replicates. As soon as the sprays had dried, 0.5 inch of simulated rain was applied to one-half of the treated plants. The plants were placed under a canvas covered steel frame, 3 by 3 by 5 inches. Water was introduced under a constant pressure through a garden sprayer attached to the top of the frame, about 15 inches above a 16-mesh screen wire tray section fitted across the entire enclosure. This apparatus gave a good distribution of droplets simulating rain falling on the plants. When all the plants had thoroughly dried, the weevils were introduced onto them and the number of live

Table 2.—Results of cage toxicity tests for boll weevil control conducted in the laboratory using insecticides indicated applied as sprays in Experiment 2 at College Station, Texas.

Treatment	Date	Dose[2]	Per Cent Mortality[1]	
			No Rain	Simulated Rain[3]
Toxaphene	9/20	4.0	64.3	24.1
	9/27	6.0	19.6	50.4
	10/6	6.0	18.0	40.4
	10/18	10.6	37.1	33.0
Average		6.5	34.8	37.0
Dieldrin	9/20	.06	26.1	24.1
	9/27	.20	27.5	33.1
	10/6	.40	12.4	1.6
	10/18	1.60	50.4	65.5
Average		.57	29.1	31.1
Aldrin	9/20	.40	48.6	18.0
	9/27	.80	80.2	27.5
	10/6	1.60	66.9	12.0
	10/18	6.40	69.6	51.4
Average		2.30	66.3	27.2

[1] Average of 4 replicates for each dose.
[2] Pounds active ingredient per acre.
[3] One-half inch of simulated rain applied to the plants after insecticidal treatment.

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and dead weevils were recorded at the end of a 3-day period.

It will be noticed that considerably higher dosages of toxaphene, dieldrin or aldrin were required to give kill in late September and October comparable to that obtained in August (Experiment 1). Apparently there were certain factors other than environmental which greatly affected the toxicity of these organic insecticides. It is assumed that these factors involve the physiology of the weevil itself.

The application of one-half inch of simulated rain did not affect the toxicity of either toxaphene or dieldrin sprays when used against boll weevils. The toxicity of aldrin spray was however, greatly reduced by the simulated rain. It is assumed that the aldrin spray was either washed off the plants or the simulated rain caused a breakdown of the chemical.

Experiment 3, table 3 had for its purpose the comparison of the toxicity of three toxaphene sprays for the control of boll weevils. The sprays were made from miscible oil concentrates containing different emulsifiers and compared under the conditions of no rain and with 0.5 inch of simulated rain, applied soon after the sprays were dry. Xylene was used as the solvent in all cases. The tests were conducted in a manner similar to that described in the previous tests. During the period from September 5 to 16, the average daily temperatures in the laboratory ranged from 76.2 to 87.7° F. and the average daily relative humidities ranged from 43.9 to 72.8 per cent as compared to a range of 67.0 to 91.9° F. and 47.1 to 93.4 per cent relative humidity in the field. During the period from September 20 to October 18 in the laboratory the average daily temperatures ranged from 73.4 to 84.9° F. and the average daily humidities ranged from 42.3 to 73.3 per cent. It will be noted that again the dosage required to give a certain kill in October was considerably higher than that required to give a comparable kill early in September. Since the temperatures and humidities did not differ greatly during the two periods, the results of these tests again indicate that factors other than environmental greatly affected the toxicity of toxaphene spray. A higher dosage was necessary to obtain a comparable kill in the field to that in the laboratory. Since the temperatures did not differ greatly, it is assumed that the wider range in percentage of relative humidity, sunshine, dew, wind, or combination of these factors is important in reducing the toxicity of toxaphene spray.

Table 3.—Results of cage toxicity tests for boll weevil control conducted in the laboratory and field using insecticides indicated applied as sprays in Experiment 3 at College Station, Texas.

Treatment	Date	Per Cent Mortality[1]				
		Laboratory			Field	
		Ave. Dose[1]	No Rain	Simulated Rain[2]	Ave. Dose[1]	No Rain
Toxaphene Emulsifier A	9/5–16	1.11	24.2		3.33	20.5
	9/20–10/18	6.8	36.4	36.2		
Emulsifier B	9/5–16	1.11	29.0		3.33	23.4
	9/20–10/18	6.8	39.8	34.1		
Emulsifier C	9/5–16	1.11	29.8		3.33	33.2
	9/20–10/18	6.8	39.5	32.0		

[1] Pounds active ingredient per acre. Averages of doses and per cent mortalities are for 4 doses, with a minimum of 3 replicates of each dose.

[2] One-half inch of simulated rain applied to the plants after insecticidal treatment.

Appropriate analysis of the detail data were made and it was found that there were no significant differences between the toxicities of toxaphene sprays, made from miscible oil concentrates, containing three different emulsifiers for boll weevil control. The toxicities of the different emulsions were not affected by the application of 0.5 inch of simulated rain.

Experiment 4, figure 1, was conducted to determine the effectiveness of toxaphene and gamma benzene hexachloride when applied as a dust and as a spray and compound *Q-137*[1] spray for leafworm control. Tests were also made to determine the effect of simulated rain on the toxicity of dust and spray formulations of toxaphene and gamma benzene hexachloride. Laboratory-reared third instar leafworms were

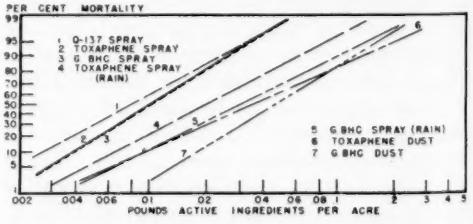

FIG. 1.—Dosage mortality curves for the toxicity of the insecticides indicated under the conditions of no rain and following one-half inch of simulated rain to laboratory-reared cotton leafworms in experiment 4

[1] 1,1,bis(p-ethyl phenyl)2,2 dichloroethane.

used and the number of live and dead worms was recorded at the end of a 5-day period after application. It was thought that experiments using leafworms as test insects would be more critical for determining the effect of simulated rain on insecticides than experiments using the boll weevil, due to the different feeding habits of the test insects. The leafworm consumes large quantities of the poisoned leaves, whereas the weevil is principally a fruit feeder and consumes comparatively small amounts of foliage.

Dosage-mortality curves for Compound *Q-137* spray, toxaphene spray and dust, gamma benzene hexachloride spray and dust and sprays of the two latter materials following one-half inch of simulated rain are compared in figure 1. The spray formulations of toxaphene, gamma benzene hexachloride, and Compound *Q-137* were equally effective. The spray formulation of both toxaphene and gamma benzene hexachloride proved more effective than the dust formulations. Simulated rain reduced the toxicity of both toxaphene and gamma benzene hexachloride sprays to a certain extent, but the toxicity of the dust formulations was reduced considerably more. Critical comparison of the median lethal dosages and their fiducal limits are shown in table 4. The results of tests shown in table 5 indicate that 0.5 inch of simulated rain, reduced the toxicity of the toxaphene and gamma benzene hexachloride dusts sufficiently to make them ineffective. Even though 0.5 inch of simulated rain reduced the toxicity of the sprays, the excessive amounts of these

Table 4.—Results of cage toxicity tests for leafworm control in the laboratory using insecticides indicated applied as sprays and dusts in Experiment 4 at College Station, Texas.

Treatment	No Rain		Simulated Rain[1]	
	MLD[2]	Slope of Line	MLD	Slope of Line
Toxaphene				
Dust	.034± .006[3]	2.13	.020[4]± .008	2.53
Spray	.011± .002	3.40		
Gamma BHC				
Dust	.046± .006	2.96	.030[4]± .005	2.36
Spray	.011± .002	3.21		
Q-137[5]				
Spray	.008± .001	2.50		

[1] One-half inch simulated rain applied to plants after insecticidal treatment.
[2] Pounds active ingredients per acre.
[3] Fiducal limits at 5% level.
[4] The dusts were washed off by the simulated rain. (See table 5.)
[5] 1,1 bis(P-ethyl phenyl)2,2 dichloroethane.

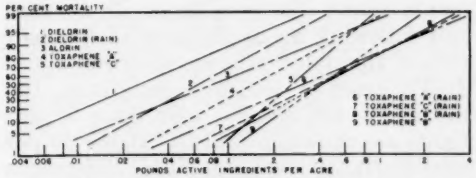

FIG. 2.—Dosage-mortality curves for the toxicity of the insecticides indicated under the conditions of no rain and following one-half inch simulated rain to laboratory-reared salt-marsh caterpillar larvae in experiment 5.

insecticides which are generally used in field applications for the control of other cotton insects would remain effective for leafworm control following at least 0.5 inch or more of rain.

Experiment 5 had for its purpose the comparison of the toxicity of toxaphene, dieldrin and aldrin sprays used for the control of the salt-marsh caterpillar. Laboratory-reared third instar salt-marsh caterpillar larvae were used and the numbers of live and dead worms were recorded at the end of a 5-day exposure period. The toxaphene sprays were made from miscible oil concentrates containing different emulsifiers as used in experiment 3, against boll weevils. The dieldrin and aldrin sprays were made from commercial miscible oil concentrates. Comparisons were also made to determine the effect of 0.5 inch of simulated rain applied soon after treatment on the toxicity of these different emulsions.

Dosage-mortality curves for the treat-

Table 5.—Results of cage toxicity tests for leafworm control conducted in the laboratory using insecticides indicated applied as dusts in Experiment 4 at College Station, Texas.

Treatment	Dose[1]	Per Cent Mortality 5 Days After Treatment	
		No Rain	Simulated Rain[2]
Toxaphene	.015	17.4[3]	11.3
	.03	55.0	24.3
	.06	68.4	9.9
	.12	85.1	15.3
Gamma BHC	.02	22.5	.0
	.04	29.1	1.5
	.06	71.5	.0
	.08	96.1	.0

[1] Pounds active ingredient per acre
[2] One-half inch simulated rain applied to plants after treatment.
[3] Average of 4 replicates for each dose.

ments under the conditions of no rain and following an application of one-half inch of simulated rain are shown in figure 2. To exact a critical comparison, the median lethal dosages and their fiducal limits are shown in table 6. At the 50 per cent mortality level, significant differences were found in the toxicity of the three toxaphene sprays made from oil concentrates containing different emulsifiers. While at the higher levels of mortality two of the emulsion sprays were more nearly equal in toxicity. It will also be noted that simulated rain reduced the toxicity of two of the spray emulsions, whereas one of the spray emulsions was not greatly affected by the simulated rain. The spray emulsion which was not affected by the simulated rain proved to be less effective for salt-marsh caterpillar control than the other two emulsions. As in experiment 4, the toxicity of certain toxaphene sprays to the leafworms was reduced by simulated rain but not of a sufficiency to cause them to be ineffective. Whereas in Experiment 2 the toxicity of toxaphene spray to the boll weevil was not reduced by simulated rain. These differences in results using different test insects may be due to the different feeding habits of the weevils and caterpillars. The tests using salt-marsh caterpillars are considered more critical than those using weevils.

Dieldrin and aldrin were more toxic to the salt-marsh caterpillar than either of the toxaphene sprays at the 50 per cent mortality level. Dieldrin proved more effective than aldrin. Aldrin and two of the toxaphene emulsions were equally effective at the higher levels of mortality. As indicated from these tests using salt-marsh caterpillars as well as the tests using boll weevils (Experiment 2), the toxicity of aldrin spray was greatly reduced by 0.5 inch of simulated rain. A dose of 0.5 pound of aldrin per acre gave 92.4 per cent mortality of salt-marsh caterpillars under the conditions of no rain as compared to 22.4 per cent mortality under the conditions of 0.5 inch of simulated rain. The toxicity of dieldrin spray was reduced by simulated rain, but not nearly so much as the aldrin spray. At the high levels of mortality, dieldrin spray retained its toxicity following simulated rain better than did the toxaphene spray.

Tests in experiment 6 were made to determine the effectiveness of toxaphene dust mixtures containing either oil or a commercial sticker when subjected to one-half inch of simulated rain. The results of these tests are shown in table 7. As in the other tests, third instar salt-marsh caterpillar larvae were used. Ten worms were released on each of the six replicate plants after treatment. The numbers of live and dead larvae were recorded at the end of 5-day period.

One-half inch of simulated rain greatly reduced the toxicity of all the toxaphene-sulphur dust mixtures. The addition of either oil or a commercial sticker had little or no effect on the residual toxicity of toxaphene-sulphur dusts following simulated rain.

SUMMARY.—In laboratory and greenhouse tests, spray formulations of toxaphene, aldrin and dieldrin proved to be more effective for boll weevil control than did the dust formulations. Considerably higher dosages of these insecticides applied as spray emulsions were necessary to give a kill in the field comparable to that in either the laboratory or greenhouse. Since the temperatures did not vary much in either location, it is assumed that the

Table 6.—Results of cage toxicity tests for salt-marsh caterpillar control in the laboratory using insecticides indicated applied as sprays in Experiment 5 at College Station, Texas.

Treatment	No Rain		Simulated Rain[1]	
	MLD[2]	Slope of Line	MLD[2]	Slope of Line
Toxaphene				
Emulsifier A	.175± .040[3]	2.92	.360± .090	2.00
Emulsifier B	.420± .074	3.21	.446± .048	2.42
Emulsifier C	.280± .042	4.24	.410± .091	2.11
Dieldrin	.028± .010	2.05	.080± .010	3.08
Aldrin	.087± .003	1.89	[4]	

[1] One-half inch simulated rain applied to plants after insecticidal treatment.
[2] Pounds active ingredient per acre.
[3] Fiducal limits at 5% level.
[4] The toxicity of aldrin spray was greatly reduced.

Table 7.—Results of cage toxicity tests for salt-marsh caterpillar control conducted in the laboratory using toxaphene dust mixtures indicated in Experiment 6 at College Station, Texas.

Treatment	Dose[1]	No. Replicates	Per Cent Mortality	
			No Rain	Simulated Rain[2]
Toxaphene-Sulphur	1.0	6	93.7	18.2
Toxaphene-Sulphur plus 5% sticker	1.0	6	91.2	11.5
Toxaphene-Sulphur plus 2% oil	1.0	6	96.3	18.7

[1] Pounds active ingredients per acre.
[2] One-half inch of simulated rain applied to dusted plants soon after treatment.

wider range in percentage relative humidity, sunshine, dew and wind or a combination of these factors, brought about a decided reduction in the toxicity of toxaphene, dieldrin and aldrin. These factors reduced the toxicity of aldrin more than either toxaphene or dieldrin.

The application of 0.5 inch of simulated rain did not affect the toxicity of either toxaphene or dieldrin sprays when used for boll weevil control in the laboratory. The toxicity of aldrin spray was, however, greatly reduced by the simulated rain.

Considerably higher dosages of toxaphene, dieldrin and aldrin were required to give kill of weevils in late September and October comparable to that obtained in August. It is assumed that certain factors other than environmental greatly affect the toxicity of these insecticides. These factors probably involve the physiology of the weevil itself.

Spray formulations of gamma benzene hexachloride, toxaphene and *Q-137* (1,1 bis(P-ethyl phenyl) 2,2 dichloroethane) proved equally effective for leafworm control. The spray formulations of gamma benzene hexachloride and toxaphene were more effective for leafworm control than the dust formulations. The application of 0.5 inch simulated rain reduced the toxicity of the spray formulations to a certain extent, but the toxicity of the dust formulations was reduced sufficiently to make them ineffective. Even though 0.5 inch of simulated rain reduced the toxicity of the sprays, the excessive amounts of these insecticides which are generally used in field applications for the control of other cotton insects would probably remain effective for leafworm control following at least 0.5 inch or more of rain.

No differences were found in the toxicity of toxaphene sprays made from miscible oil concentrates containing three different emulsifiers in tests for boll weevil control. In tests for salt-marsh caterpillar control, there was a difference in the toxicity of the sprays made from oil concentrates containing these different emulsifiers. The toxicity of two of the emulsifiable sprays was reduced by the simulated rain in the experiment in which salt-marsh caterpillars were used as the test insects. Apparently the type of emulsifier used in making the miscible oil concentrate affects the toxicity of the spray emulsion as well as its residual toxicity following rains.

Dieldrin spray proved more toxic to the salt-marsh caterpillar than either of the toxaphene sprays. Toxaphene spray proved as toxic to the salt-marsh caterpillar as aldrin spray at the high levels of mortality. The toxicity of aldrin sprays were greatly reduced by simulated rain. The toxicity of the dieldrin sprays was not reduced by simulated rains as much as were the aldrin sprays.

One-half inch of simulated rain greatly reduced the toxicity of toxaphene-sulphur dusts. The addition of either oil or a commercial sticker to toxaphene-sulphur dusts had little or no effect on the residual toxicity following simulated rain.

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Life History of the Green Peach Aphid on Peach and Its Relation to the Aphid Problem on Potatoes in Washington

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The green peach aphid, *Myzus persicae* (Sulz.), causes a moderate amount of damage to potatoes in central Washington each year but was not considered a major pest of patatoes in that section until 1938, when the leafroll disease, carried by the aphid, occurred in epiphytotic proportions (Locke 1948). Observations made in several potato districts of Washington showed that this aphid appeared on potatoes earlier in the season and also that losses from leafroll were greater at Yakima than in any other district. This fact indicated that there probably was a greater abundance of satisfactory overwintering host plants at Yakima than in the other potato districts.

The green peach aphid overwinters in the egg stage on several species of *Prunus*. Patch (1925) compiled a list of hosts of the aphid and concluded that the peach tree was the true overwintering host. In the absence of peach trees, Simpson & Shands (1949) found that species of wild plum also were satisfactory hosts. Heinze & Profft (1938) and Heinze (1948) observe the greatest abundance of the green peach aphid and the most severe losses from aphid-borne diseases in parts of Germany where peach trees were abundant.

Few peach trees are present in any potato district of Washington except the Yakima Valley, where approximately 8000 acres of potatoes are grown annually in close proximity to 6000 acres of peach orchards. Because of the prevalence of peach trees at Yakima, a study of the green peach aphid on that host was conducted in 1949 to determine the time of production of winged spring-migrant aphids that could infest the potatoes and spread the leafroll disease.

Observations in the peach orchards in the spring of 1949 showed 40 aphid eggs per 6 inches of twig at some locations, although the average infestation was much less. Most of the commercial orchards were sprayed or dusted with aphidicides after the eggs had hatched. These applications were highly effective in giving immediate control, but the aphids that survived the treatments increased rapidly as propagation continued. Numerous small farm orchards containing one or more peach trees were not dusted or sprayed, and enormous populations of wingless and winged green peach aphids were produced on those trees.

The life-history studies reported herein show that, starting with the third generation in the spring, variable percentages of winged aphids are produced on peach trees. Attempts made to induce the winged aphids to deposit nymphs on the peach leaves when confined in cages on the trees failed, except in rare cases when one to three nymphs were produced before the adult aphid dies. Not all the aphids of any generation produced on the peach trees were winged, and the production of both wingless and winged aphids may continue throughout the season at Yakima.

The production of variable numbers of winged aphids in each generation of the green peach aphid on peach trees, except in the first and second generations, insures a continuous production of winged migrant aphids for the infestation of potatoes and other host plants throughout the season. Starting with one egg in the spring, 400 winged aphids can be produced in the third generation. Usually less than half the aphids of each generation except the first and second are winged. The number of winged aphids produced after several generations would be tremendous were it not for depredations of predators and parasites and for accidental deaths.

Observations have shown that potato fields near peach orchards become infested with the green peach aphid within a few days after the first winged aphids are observed on peach trees in the spring. Not only are these fields infested earlier but the seasonal populations also become greater in locations near the peach orchards.

[1] In cooperation with the Washington Agricultural Experiment Station and the Washington State Department of Agriculture.

METHODS AND EQUIPMENT.—The aphids were reared in small cages placed over twigs of peach trees in a commercial orchard. The cage was made in two parts. The top part was a celluloid cylinder 2.5 inches in diameter and 4 inches high; the top was covered with cheesecloth. The bottom part of the cage was a celluloid ring which fitted closely around the lower end of the cylinder. The bottom of the celluloid ring was covered with 40-mesh screen wire, which had a metal eyelet, or grommet, in the center into which fitted a No. 2 rubber stopper. The stopper had a 0.25 inch hole through the center from end to end, and was cut lengthwise to the center.

In setting up a cage for rearing aphids the twig was wrapped with cotton about 1 inch below a bud or leaf tuft and was enclosed in the cut rubber stopper. Next the twig was inserted into the cage through the grommet opening and the rubber stopper was fitted into the grommet. The twig therefore remained on the tree and also supported the cage. The cylinder or top of the cage could be removed for observation or removal of some of the aphids with very little disturbance of other aphids feeding on the buds or leaves within.

Because of rapid growth of leaves and twigs, occasional pruning was done in the cages. This also served to concentrate the aphids in a relatively small area where examinations could be made more easily. A camel-hair brush was used for removing or transferring the aphids.

Cage studies were started on March 4, 1949, with stem mothers that hatched on that day. The nymphs were confined singly in cages and were not disturbed until mature. On the day the first nymphs were found and each day for 4 days thereafter, the stem mothers were changed to other cages. Thereafter, the nymphs found in each cage were counted and destroyed, but the stem mothers were not disturbed. The individual nymphs used in starting each successive generation remained in the original cages and the reproducing adults were transferred to other cages and cared for as described for the stem mothers. Approximately equal numbers of nymphs were used to start each generation and the number reared to maturity represented approximately one-third of the number present at the beginning.

The Egg.—Observations in 1948 and 1949 showed that the eggs were deposited on peach trees from the last of October until the second week of December. The eggs are green at first, but changed to glistening black after 2 to 3 days. Although eggs were found on all trees within an orchard, the greatest number were on the border row, and more eggs were found on the south than on the north side of a tree. These observations are in agreement with those of Moericke (1941) at Bonn, Rhineland, Germany.

At Yakima the eggs started hatching in the last 2 weeks of February or the first 2 weeks of March. Ninety per cent of the eggs had hatched on March 1, 1948, and on March 9, 1949. The mean temperature for February was 31.2° F. in 1948 and 29.6° in 1949. Taylor (1908) found hatching under way on February 16, 1907, at Grand Junction, Colo. Moericke (1941)observed hatching at Bonn, Rhineland, on February 1, 1938, and by the middle of February 1939. Heinze & Profft (1938) reported hatching at Berlin, Germany, on March 16, 1937, and March 10 to 12, 1938. Fenjves (1945) did not observe hatching at Zurich, Switzerland, until April 14, 1941, and March 28, 1942.

The Stem Mother.—The newly hatched stem mothers are somewhat rectangular in shape and olive green or black. The beak is unusually large and strong, and when it is inserted in a peach bud the small nymph can not forcibly be removed without breaking the rostrum. Slight color changes occur with each moult; of 31 mature stem mothers 8 were green, 13 were red, and 10 were various shades of red mixed with green.

No attempt was made to determine the time required for each nymphal stadium or the time between the last moult and the production of young. In this study the developmental period was considered to be the time from the hatching of the external egg, or the birth of the aphid, to the birth of the first aphid nymphs of the following generation.

The developmental period of the stem mothers ranged from 25 to 32 days (average 29), the reproductive period from 8 to 36 days (average 19), and the total length of life from 37 to 65 days (average 50). After the stem mothers started giving birth to young, from 1 to 16 (average 4) were born each day until 1 or 2 days prior

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Table 1.—Summary of life history and reproduction of the stem mother and 13 agamic generations of wingless green peach aphids reared in cages on peach trees. Yakima, Wash., 1949.

Generation	Number of Females	Date of Birth	Developmental Period (days)		Reproductive Period (days)		Young per Female (number)		Young Produced per Day (number)		Length of Life (days)	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Stem mother	31	Mar. 4–7	25–32	29.4	8–36	19.1	19–136	73.1	1–16	3.8	37–65	49.5
1	29	Apr. 4–5	11–13	11.4	13–36	25.7	37–132	88.1	1–10	3.4	26–39	37.6
2	24	16–18	10–14	11.9	7–30	16.1	6–87	46.9	1–11	2.9	19–45	28.5
3	16	28–29	11–13	12.1	3–27	15.5	7–80	43.5	1–10	2.8	15–46	29.8
4	24	May 10–11	8–12	10.5	4–23	13.5	7–65	30.9	1–9	2.3	14–35	25.0
5	17	20–22	9–12	10.2	1–20	8.9	1–58	20.0	1–8	2.2	11–30	20.8
6	14	29–										
		June 1	7–11	8.5	5–22	11.2	3–64	22.2	1–7	2.0	12–30	21.2
7	37	6–10	9–11	9.8	2–23	12.5	2–55	24.8	1–9	1.9	11–33	23.1
8	25	19–20	8–13	10.8	1–22	8.2	1–49	17.2	1–8	2.0	14–34	19.8
9	21	July 1–2	8–11	9.7	2–17	8.2	3–32	13.0	1–6	1.5	12–27	18.8
10	25	11–12	7–15	10.4	1–16	7.3	3–27	10.8	1–5	1.4	12–27	19.1
11	24	21–23	8–12	9.5	1–14	5.4	2–21	7.7	1–4	1.4	10–28	15.8
12	26	31–										
		Aug. 2	7–14	10.8	1–9	3.5	1–10	4.3	1–3	1.2	10–25	15.2
13	10	9–13	10–14	12.3	1–10	3.4	1–7	4.3	1–4	1.2	14–20	17.3

to death. The number of young produced by the stem mothers ranged from 19 to 136 per female (average 73).

The Agamic Generations.—Simpson & Shands (1949) were able to maintain colonies of the green peach aphid in cages on wild plum in Maine beyond the time of the return migration to plum in the fall. Other workers who observed the development of the aphid on peach trees reported that only a few generations were produced until all individuals became winged and left the trees. Taylor (1908) mentions only three spring generations on peach in Colorado. Heinze (1948) observed five spring generations in Germany and Fenjves (1945) reported from three to five generations in Switzerland.

At Yakima 1 stem mother and 14 agamic generations were reared on peach trees from March 4 to September 2. Stem mothers and the first agamic generation were all wingless, but some winged aphids occurred in each of the later generations. The production of winged aphids is discussed separately. The summary of the seasonal production of the wingless aphids throughout the period of reproduction on peach trees is given in table 1.

The aphids of the agamic generations developed more rapidly than the stem mothers, the seventh generation from the egg developing most rapidly. The average time required for development was as follows: Agamic generations 1 to 3 maturing in April, 11.8 days; generations 4 and 5 maturing in May, 10.3 days; generation 6 maturing in June, 8.5 days; generations 7 to 9: maturing in June and July, 10.3 days; and generations 10 to 13 maturing in July and August, 10.7 days. The reproductive period of the agamic adults ranged from 1 to 36 days and the average for 292 individuals of the agamic generations was 10.7 days.

The maximum number of nymphs produced by a female in the agamic generations was 132, and this occurred in the second generation from the egg. Females of this generation produced an average of 88.1 nymphs each, or nearly twice the number produced in any of the later generations. The average number of young produced by 292 agamic females of various generations was 27.4. There was no

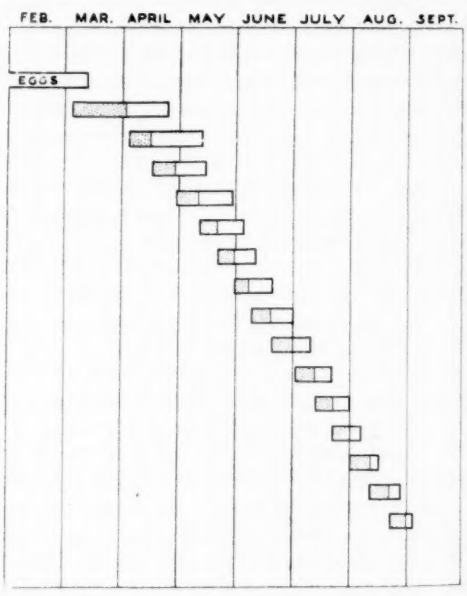

FIG. 1.—Seasonal production, average length of the developmental period (stippled area), and length of life (entire block) of the stem mother and 14 agamic generations of the green peach aphid reared in cages on peach trees. Yakima, Wash., 1949.

regularity of reproduction in any generation, although the average number of nymphs produced per female declined in each succeeding generation. The maximum number of nymphs produced by a female during a single day was 11 in the second agamic generation. Nymphs were deposited without regard for time of day.

The length of life of agamic females ranged from 10 to 49 days, and the average was 22.4 days. In general, the length of life decreased during the spring and summer. The seasonal production of consecutive generations of the green peach aphid in cages on peach trees in 1949 is given in figure 1.

In order to determine the possible direct effect of crowding as a cause of the production of winged aphids, from 1 to 37 nymphs of the green peach aphid were placed in cages on peach trees. The size of the leaf tuft available for feeding was such that 25 p or more aphids per cage could be considered as crowding. The cages were undisturbed until all aphids had matured and then the percentage of winged aphids in each cage was determined. The results did not show any relationship between the numbers present in the cages and the percentages of winged aphids produced.

CONCLUSIONS AND SUMMARY.—Large numbers of the green peach aphid, *Myzus persicae* (Sulz.), are produced on peach trees in the spring at Yakima, Wash. Starting in the third generation, both winged and wingless aphids are produced in each generation. Barring the depredations of predators and parasites, a number of wingless aphids are produced in each generation. Their function is to maintain the aphid on the trees throughout the summer.

Winged Migrants.—Taylor (1908) in Colorado and Moericke (1941) in the Rhineland found some winged aphids produced in the second generation on peach trees. Fenjves (1945), Heinze & Profft (1938), Heinze (1948), and Patch (1925) did not observe the production of winged aphids until the third generation. Under laboratory conditions, however, Heinze (1948) did not observe winged aphids until the fourth generation, and he concluded that temperature was an important factor in the time of production of the first winged aphids. At Yakima the first winged aphids were observed in the third generation.

Taylor (1908) also reported that the winged aphids "spread to other leaves and trees to start new colonies." Fenjves (1945), Heinze & Profft (1938), and Moericke (1941) observed that the winged aphids fed for a short time on peach foliage, but did not produce young until they reached the secondary host plants. At Yakima a total of 3 nymphs were produced by 152 winged aphids reared and confined on peach trees until death. None of the nymphs reached maturity.

Table 2.—Green peach aphids produced from nymphs of stem mother and 14 agamic generations and confined as single aphids per cage on peach trees. Yakima, Wash., 1949.

GENERATION	TIME OF MATURITY	APHIDS NUMBER	PER CENT WINGED
Stem mother	Apr. 1 to 15	31	0
1	15 to 17	32	0
2	27 to 30	32	6
3	May 10 to 11	32	34
4	19 to 23	52	52
5	29 to June 1	35	49
6	June 8 to 10	44	64
7	18 to 21	49	6
8	28 to July 2	55	42
9	July 9 to 13	54	56
10	18 to 26	43	35
11	29 to Aug. 3	30	13
12	Aug. 8 to 15	28	7
13	19 to 25	15	33
14	31	1	100

Various percentages of the aphids of the second to fourteenth agamic generations reared on peach trees at Yakima were winged (Table 3). Since only one aphid was permitted to develop in a cage, the production of winged aphids was not caused by crowding. Both winged and wingless aphids were produced at the same time and under similar conditions. The trend of production of winged aphids was not unlike that observed by Heinze (1948), who reported that under laboratory conditions about 23 per cent of the fourth generation, 50 per cent of the fifth generation, and 40 per cent of the sixth generation were winged.

The first colonies of the green peach aphid are found on potatoes adjacent to peach orchards within a few days after the first winged aphids are produced on the trees. The aphids are slow to reach potatoes some distance from the orchards at Yakima, and the lack of peach trees in other potato districts of Washington appears to be responsible for the late in-

festation of the potato crops in those areas.

Fifteen generations of the green peach aphid, consisting of the stem mother and 14 agamic generations, were reared in small celluloid cages on peach trees at Yakima from March 4 to September 2, 1949. The average length of life of the stem mothers was 49.5 days and they produced an average of 73.1 young each. The average length of life of the agamic generations ranged from 37.6 days for those born in April to 15.2 days for those born in August. The maximum number of aphids produced per female was 132 in the spring, 55 in June, and 10 in August. An average of 27.4 nymphs per aphid was produced by 292 aphids during the season.

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Pre-Silking Sprays to Control Corn Earworm and Fall Armyworm[1]

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The use of oil for the control of the corn earworm, *Heliothis armigera* Hbn., in sweet corn has come into use through a gradual process. Barber (1939) showed the value of the use of pure white mineral oil injected into the silk channel for the control of corn earworm. Later (Barber 1940; Blanchard & Satterthwait 1945a) pyrethrum and DDT were added to the oil to increase its effectiveness.

In order to facilitate larger scale applications at decreased labor costs Blanchard & Satterthwait (1945b) developed a spray consisting of an emulsion of oil and DDT or some other chlorinated insecticide. As a result of their work it is now generally recommended that the spray be made up of 3 quarts of 25 per cent emulsifiable DDT and 2.5 gallons of a light white oil and this mixture then diluted to 25 gallons. Two or three applications at 2 or 3 day intervals are necessary, starting at about 10 per cent silk. The emulsion is applied with a fine spray nozzle at the rate of 25 gallons to the acre.

This procedure works well in South Carolina for spring planted sweet corn but when applied to summer planted corn ineffective control is obtained. This paper shows the results of such a spray program and the modifications necessary for the control of the corn earworm and fall armyworm, *Laphygma frugiperda* (S, & A,), in sweet corn planted during the summer in the Piedmont area of South Carolina.

MATERIALS USED AND PROCEDURES OF APPLICATION.—The oil used in the investigation was a light white oil, viscosity 67 seconds at 100° F., with a boiling range of 543 to 846° F.

The DDT, methoxychlor and TM-1[3] were 25 per cent emulsifiable materials. Chlordane was prepared as a 75 per cent concentrate, and toxaphene as a 60 per cent concentrate. Therefore, smaller quantities of these were used in order to

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[3] Test material 1 (*Dilan*) Commercial Solvents Co.

obtain equal concentrations of the active material in the final spray.

DDT, methoxychlor and TM-1 were mixed with oil at the rate of 3 quarts of the 25 per cent material to 2.5 gallons of oil. Chlordane was mixed at the rate of 1.0 quart, and toxaphene at 1.2 quarts. These mixtures were then diluted with water to make 25 gallons.

Application to the corn was made with a 5-gallon compression sprayer, as this type of equipment is most readily available to farmers in the South. The spray was applied at the rate of 25 gallons per acre. Both sides of the row were sprayed.

RESULTS.—Two one-fourth acre plantings of sweet corn were used for test plots. The first planting silked from August 2 through 12, the second from August 31 through September 5.

The first planting was divided into four plots, so as to test three experimental procedures of early spraying for the control of the corn earworm. DDT and TM-1 were used. One plot of the first planting was sprayed on August 3, when approximately 10 per cent of the corn was in silk. This plot was sprayed again on August 5, 8, and 12.

The second plot was sprayed on August 5, 8, and 12. The third plot was sprayed on August 8 and 12. The fourth plot was used as a check. All tests were replicated.

As may be seen in table 1 none of these procedures gave a satisfactory control of the corn earworm and the fall armyworm. However, four applications gave better control than did two, with 67 to 77 per cent infestation in the best control.

With the results of the tests on the first planting in mind, the procedure was completely revised for the tests on the second planting. Besides revising the procedures, three other insecticides were tested.

Observations of the first planting of sweet corn showed that there were two possible explanations why the spraying started the day after silking failed to give control. Infestation could occur before and after the normal spraying period. Part of the infestation occurred before any silks had appeared and part after the silk tips had turned brown. Under the humid conditions occurring at this time of the year the silks only partially turn brown and some of them remain green even up to the last picking of the corn.

In one plot of the second planting spraying was started before any silks appeared on the ears, at a time when no more than 1.5 inches of the ear actually showed from the leaf sheath. Two sprays were applied before the silks appeared, on August 28 and 30, followed by two sprays after silking on September 1 and 4.

In the second plot the sprays were applied on September 1 and 4. Sprays were applied on the third plot on September 1 and 4, followed by four other sprays after some brown silks had appeared. These so-called post-silking sprays were applied on September 10, 12, 14, and 17. In the fourth plot eight applications of sprays were applied starting with the two pre-silking sprays, two during silking, and four post silking sprays. By September 6 over 90 per cent of the corn showed brown silks. The corn was picked September 18 to 22.

The results of the second planting experiments are shown in table 2. The importance of the pre-silking sprays is clearly shown. With all of the materials except chlordane pre-silking sprays reduced the infestation below that occurring when only the regular schedule was applied. TM-1 and DDT were definitely superior to the other materials. Results with toxaphene are not included because there were not enough replicates with this material to give accurate data. However, the single test performed using this material with oil

Table 1.—Results on first planting of fall sweet corn.

INSECTICIDE	CONCENTRATION OF EMULSION	AMOUNT USED PER 25 GALLONS	TIME OF SPRAYING	INFESTATION
TM-1	25%	3 Qts.	Aug. 3, 5, 8 & 12	97%
			5, 8 & 12	86
			8 & 12	91
DDT	25%	3 Qts.	Aug. 3, 5, 8 & 12	67%
			5, 8 & 12	77
			8 & 12	85

Table 2.—Per cent infestation of late fall sweet corn by corn earworm and armyworm.

INSECTICIDE	WITH PRE-SILKING PLUS REGULAR SPRAYS	REGULAR SPRAYS	WITH REGULAR PLUS POST-SILKING SPRAYS	WITH PRE-SILKING, REGULAR AND POST-SILKING SPRAYS
Chlordane	56	54	94	54
TM-1	3	72	53	15
Methoxychlor	80	91	84	68
DDT	0	67	30	18
Check	100			

indicates that it is probably as good as TM-1 or DDT. Methoxychlor and chlordane were of little value. Also late sprays or post-silking sprays proved to be of little value.

Analyses of these four experiments indicated that the main reason for failure to obtain control in the first planting was because infestation was occurring before the silks had appeared. In fact upon examining the corn many worms were found boring through the shucks and into the ear before the silks appeared.

All of the spray materials gave some burning of the shucks and leaves of the corn and some of the tip grains failed to be pollinated. Check ears were so destroyed by the worms that it was impossible to tell the exact extent of pollination. With most of the ears on the check plot all that remained was a mass of frass.

By following a schedule of pre-silking sprays a crop of corn was produced under conditions of severe population of corn earworm and armyworms occurring in South Carolina in the fall of the year.

In addition to the experimental spray program conducted on sweet corn, observations were made during the year on the course of infestation of tomatoes by the corn earworm.

The initial infestation in tomatoes started at a high level (85 per cent) and after a few weeks the infestation dropped to approximately 40 per cent. It remained at about 40 per cent for 2 to 3 weeks when a sudden drop in the infestation occurred. In the course of approximately 2 weeks the infestation dropped to 10 per cent. The infestation then remained at the 10 per cent level for another 2 weeks before it started to rise in late planted tomatoes. Unless there is a high population of nearly full grown larvae in the field the greatest percentage of infestation occurs in the young fruit. With these observations in mind a direct correlation was established between the drop in infestation in the young tomato fruits and the period of silking of sweet corn and field corn. It would appear that the moth has a definite preference for the corn in depositing eggs. These observations confirm those made in California (Michelbacher *et al.*) and other states in the host preference of the corn earworm moth.

The later rise in infestation resulted from an increase in the moth population so that even though corn was still in silk, sufficient moths were present to lay an increased quantity of eggs on the tomato plants.

Further observations established that the initial high infestation in tomatoes was caused by rather uniform emergence of first brood moths resulting in a rather high initial population which later tapered off until the summer build-up.

SUMMARY.—Preliminary tests were conducted in the Piedmont area of South Carolina during 1950 to test the Blanchard method of treating sweet corn for corn earworm control. In corn planted during the summer ineffective control is obtained if the regular spray program is followed. If two extra sprays are added before silking begins infestation can be reduced from 100 per cent in the checks to less than 10 per cent in the sprayed plots. Some burning was experienced with all of the spray materials and a slight decrease in pollenation appeared to have resulted from the spray program but the extent could not be determined because of the severe infestation in the check plots.

Some additional observations on tomatoes showed that the corn earworm adult will deposit eggs on green corn silks in preference to young tomatoes.

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Abnormal Increase of *Coccus hesperidum* in Citrus Groves Treated with Parathion[1]

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The soft (brown) scale, *Coccus hesperidum* L., is distributed throughout the world and feeds on a wide variety of plants, both in the greenhouse and out of doors. It is found in all the commercial citrus-producing regions of California, but is normally only a minor pest of citrus because of highly effective parasites. In 1947 however, it became a major pest in certain groves after experimental applications of parathion for the control of yellow scale *Aonidiella citrina* (Coq.), and citricola scale, *C. pseudomagnoliarum* (Kuw.).

Since 1947, abnormal population increases of soft (brown) scale have been observed in many groves treated with parathion. Preliminary investigations indicate that these increases are the result of a striking resistance of this species to parathion, coupled with the susceptibility of its parasites to parathion and their consequent elimination from treated groves for relatively long periods (Bartlett & Ewart 1951). Pritchard & Beer (1949) reported that a spray containing 0.5 pound of actual parathion per 100 gallons of water killed all the immature stages of soft (brown) scale on Phoenix palm seedlings but did not affect the adults.

The effect of parathion on other species of unarmored scales has been reported by various other workers. According to Asquith (1949), 98 per cent of the European fruit lecanium, *Lecanium corni* Bouche, on peach trees were killed with a spray containing 1 pound of 25 per cent parathion wettable powder plus 1 gallon of petroleum oil per 100 gallons of water, when applied to the trees during the delayed dormant period. This spray, however, killed less than 50 per cent of the terrapin scale, *L. nigrofasciatum* Perg., on the same trees. Neiswander (1949) reports 100 per cent mortality of *L. fletcheri* Ckll. on arborvitae, when treated with a spray containing 1 pound of 25 per cent parathion wettable powder per 100 gallons of water. Studies in California citrus groves (Carman & Ewart 1950) have shown that parathion will control citricola scale, cottony-cushion scale, *Icerya purchasi* Mask., and black scale, *Saissetia oleae* (Bern.).

It should be pointed out that not all groves treated with parathion have developed abnormally high populations of soft (brown) scale, even where relatively high dosages were applied. Abnormal population increases that have followed parathion treatments have been extensive, however, and have been characterized by distribution of the scales on the leaves and small branches throughout the trees, unattended by ants. In general, the greatest number of scales have been found on branch terminals in contact with the ground. In untreated groves soft (brown) scales are normally found in colonies restricted to occasional branches, and are almost always attended by ants.

To develop information on the relation between parathion treatments and increases in soft (brown) scale populations a survey was made in 1949 and 1950 in approximately 100 experimental plots and in 22 commercially treated groves in which parathion had been applied for the control of citricola scale, black scale, California red scale, *Aonidiella aurantii* (Mask.), or yellow scale. The results of this survey are summarized in this report.

Experimental Methods and Results.—Post-treatment counts of soft (brown) scale were made on leaves or 1-foot branch terminals according to standard methods (Ebeling 1950) used in estimating citricola scale insect populations. Unfortunately, pretreatment population levels of soft (brown) scale could not be determined in many of the plots because parathion treatments had been applied for the control of other insects before the survey was started. It was possible, however, to make direct comparisons between soft-scale populations in parathion-treated plots and in untreated plots or in plots treated with materials other than parathion.

The survey disclosed a great amount of variability in soft (brown) scale popula-

[1] Paper No. 680, University of California Citrus Experiment Station, Riverside, California.

tions in different plots and groves following parathion treatments. In certain groves, however, there was a relationship between the magnitude of the population and the dosage of parathion applied or the number and timing of treatments.

The data in table 1 show the effect of different dosages of parathion, and of single and double treatments, on a grove of navel oranges in Tulare County, California (Grove 1), and in a grove of Valencia oranges in Orange County (grove 2). In grove 1 the dosages of parathion applied on July 15, 1947, in plots 1 to 5, ranged from 1 to 3 pounds of 25 per cent wettable powder per 100 gallons of water. Population counts made one year later on July 16, 1948, showed that with increase in dosage from 1 to 2.5 pounds per 100 gallons there was a corresponding increase in the population of soft (brown) scale. There was no increase in the population, however, when the dosage was increased from 2.5 to 3 pounds per 100 gallons (compare plots 4 and 5). No soft (brown) scale was found in plot 8, which was treated with a combination of parathion, DDT, and kerosene, possibly because of the toxicity of DDT-kerosene spray to this species. There was no increase in the soft (brown) scale population in plot 9, which was treated with light-medium oil containing 0.5 per cent rotenone. Plots 1 and 2 were re-treated on July 29, 1948, and renumbered as plots 6 and 7, respectively. The counts of July 16, 1948, provided a pretreatment population level for plots 6 and 7, and a comparison between these counts and the November counts shows a very high increase in the number of soft (brown) scale present.

In grove 2 (Table 1), plots 10, 11, and 12 were treated with 25 per cent parathion wettable powder at 1, 1.5, and 2 pounds per 100 gallons of water, respectively, on June 10, 1949. Population counts on August 22, and September 22, 1949, showed no significant differences in the effects of the 1 and 1.5 pound dosages, but a relatively high number of scales were found in plot 12, which was given a 2-pound dosage. Counts made on November 17, 1949, showed that the soft (brown) scale population in this grove was greatly reduced; this reduction was probably caused by the very effective entomophagous insects in the grove. Plots 13 and 14 were

Table 1.—Effect of various dosages of parathion, and of single and double treatments, on populations of soft (brown) scale in a navel orange grove, Tulare County, California (Grove 1) and in a Valencia orange grove, Orange County (Grove 2).[1]

Plot No.[2]	Material and Amount per 100 Gal. Water[3]	Date of Treatment	Average No. of Live Scales per Unit on Date of Count		
	Grove 1		10 Leaves (7-16-48)		10 Leaves (11-24-48)
1	Parathion (25-W), 1 lb.	7-15-47	3.0		—
2	Parathion (25-W), 1.5 lb.	7-15-47	12.0		—
3	Parathion (25-W), 2 lb.	7-15-47	28.0		0.2
4	Parathion (25-W), 2.5 lb.	7-15-47	61.0		5.6
5	Parathion (25-W), 3 lb.	7-15-47	31.0		1.4
6	Parathion (25-W), 4 lb.	7-29-48	3.0		49.0
7	Parathion (25-W), 4 lb.	7-29-48	12.0		36.0
8	Parathion (25-W), 1 lb.; DDT (tech.), 2 lb.; and kerosene, 3 gal.	7-15-47	0.0		0.0
9	Light-medium oil (0.05% rotenone), 2 gal.	7-15-47	0.0		0.0
	Grove 2		10 Leaves (8-22-49)	1-Ft. Terminal[4] (9-22-49)	10 Leaves (11-17-49)
10	Parathion (25-W), 1 lb.	6-10-49	2.0	0.2	0.0
11	Parathion (25-W), 1.5 lb.	6-10-49	0.5	0.1	0.0
12	Parathion (25-W), 2 lb.	6-10-49	3.5	1.3	0.0
13	Parathion (tech.), 1 lb.	6-10, 8-3-49	3.0	5.9	1.3
14	Parathion (tech.), 6 oz.	6-10, 8-3-49	1.5	6.3	2.8
15	Untreated check	—	0.0	0.0	0.0

[1] Spray applied with conventional high-pressure spray equipment at a rate of approximately 3000 gal. per acre.
[2] Plots 1 and 2 were re-treated on July 29, 1948, and renumbered as plots 6 and 7, respectively.
[3] W = Wettable powder (expressed in percentage).
[4] Approximately 30 leaves.

Table 2.—Post-treatment changes in populations of soft (brown) scale following spray application with two different types of equipment for control of citricola scale in a mixed planting of orange and grapefruit trees in southern California.

Spray Application (7-26-49)	Parathion (Pounds 25% Wettable Powder in 100 Gal. Water)	Average No. of Live Soft Scales per 1-Ft. Terminal[1] on Date of Count	
		12-1-49	3-24-50
With conventional high-pressure reciprocating-type pump at approximately 2000 gal. per acre	0.5	6.8	0.1
	0.75	1.2	0.0+
	1.0	3.5	0.0
	1.5	49.2	0.7
With spray duster at 100 gal. per acre	4.0	0.0	0.0+
	5.0	0.3	0.0
	6.0	1.4	0.1
	8.0	0.3	0.8
None (check)	—	0.0	0.0+

[1] Approximately 30 leaves.

Table 3.—Effect of parathion-petroleum oil sprays on populations of soft (brown) scale on navel orange trees in central California.[1]

Material and Amount per 100 Gal. Water[2]	Average No. of Live Scales per 1-Ft. Terminal[3] on Date of Count	
	10-25-49	12-16-49
Parathion (25-W), 1 lb.	0.4	1.1
Parathion (25-W), 1.5 lb.	0.4	15.8
Parathion (25-W), 0.5 lb.; and light-medium oil, 1 gal.	0.0+	0.0
Parathion (25-W), 1 lb.; and light-medium oil, 1 gal.	0.2	0.0
Untreated check	0.0	0.0

[1] Spray applied 5-18-49 with conventional high-pressure spray equipment at a rate of approximately 3500 gallons per acre.
[2] W = Wettable powder (expressed in percentage).
[3] Approximately 30 leaves.

sprayed with parathion on June 10, and again on August 3, 1949. Counts on September 22, 1949, showed very high populations of soft (brown) scale in these plots in comparison with those in the plots sprayed a single time, or in the untreated check plot. Even in the plots sprayed twice, the populations of soft (brown) scale were greatly reduced by entomophagous insects by November 17, 1949.

Relatively low volume applications of parathion sprays for control of citricola scale also caused some increase in soft (brown) scale populations. Table 2 shows the comparative effects of two types of equipment commonly used for applying insecticides to citrus trees. The spray duster was a multi-nozzled, air-blast type of equipment especially designed for uniform applications of sprays to citrus trees. The amount of spray applied with the spray duster ranges from a minimum of 20 gallons to a maximum of 1000 gallons per acre, but treatments usually range from 100 to 400 gallons per acre. Conventional spray equipment is used to apply sprays by hand from a reciprocating-type pump under high pressure at 2000 gallons or more per acre, although the size of the trees determines the amount applied, and much lower gallonages would be used on smaller trees. All the plots sprayed with conventional-type equipment (Table 2) and treated with 0.5 to 1.5 pounds of 25 per cent parathion wettable powder per 100 gallons of water, at a rate of 2000 gallons per acre, showed an increase in soft (brown) scale populations. In the plots sprayed with spray-duster equipment at only 100 gallons per acre, there was some increase in scale populations when 5, 6, and 8 pounds of parathion were used per acre, but these increases were relatively slight when compared with those in plots sprayed with the conventional equipment.

Petroleum oil sprays to which parathion was added generally resulted in lower populations of soft (brown) scale than did parathion sprays without oil. There were usually more soft (brown) scales in plots treated with parathion-petroleum oil sprays than in untreated plots. The data in table 3 show that the populations of soft (brown) scale on October 25 were slightly higher in the two plots sprayed with parathion than in the two plots sprayed with parathion-oil combinations. On December 16 and June 25 there were many more scales in the parathion-sprayed

Table 4.—Post-treatment changes in populations of soft (brown) scale following application of parathion in four different spray schedules on navel orange trees in southern California.

Plot No.	Treatment Schedules, 1948 and 1949[1]	Average No. of Live Scales per Unit on Date of Count		
		10 Leaves (2-8-50)	10 Leaves (3-15-50)	1-Ft. Terminal[2] (7-10-50)
16	Feb. and Apr.	34.5	34.0	0.0
17	June and Aug.	15.5	11.0	0.0
18	Apr., June, and Aug.	219.5	239.0	0.0
19	Feb.	3.5	1.5	0.0

[1] Parathion 25 per cent wettable powder was used in all spray treatments at the rate 4 pounds per 100 gallons of water, applied with conventional high-pressure spray equipment at the rate of approximately 3000 gallons per acre.
[2] Approximately 30 leaves.

plots than in the parathion-oil-sprayed plots.

Table 4 shows post-treatment changes in soft (brown) scale populations in 1950, following applications of parathion in 1948 and 1949 in four spray schedules. The greatest population increases occurred in plot 18, in which treatments were applied in April, June, and August of both years. The lowest populations occurred in plot 19, in which a single treatment was applied in February of both years. Populations were similar in plot 16 (treated in February and April of both years) and plot 17 (treated in June and August of both years), the only difference being that parasitism was observed earlier in plot 16 than in plot 17. Parasites controlled the scales in all the plots by July 10, 1950.

Comparisons between soft (brown) scale populations in parathion-treated plots and in plots treated with other insecticides were also made throughout the survey. The comparative effects of organic phosphates and other insecticides, when applied to Valencia orange trees, are shown in table 5. Organic phosphate compounds included parathion, 0,0-dimethyl S-(2-oxo-2-ureidoethyl)-dithiophosphate (*TM-3901*),[2] S-carbamylmethyl 0,0-dimethyl dithiophosphate (*TM-3869*),[3] para-oxon,[4] and ethyl p-nitrophenyl thionobenzenephosphonate (*EPN*).[5] Other insecticides used were dieldrin,[6] aldrin,[7] rotenone, DDT, TDE,[8] methoxychlor,[9] and DFDT.[10]

A post-treatment comparison of plots treated with parathion, *EPN*, and para-oxon at the same dosage may be made by comparing soft (brown) scale populations present in plots 20, 21, and 22, respectively, on September 22, 1949. The double parathion treatment in plot 20 caused the greatest increase in scale population; the single-treated para-oxon plot ranked second. When comparable dosages of actual compounds were used, plot 2 which was treated with para-oxon, showed a much greater increase in soft (brown) scale than did plot 23, which was treated with parathion. Plots 25 and 26, treated with sprays containing *TM-3901* and *TM-3869*, respectively, had approximately the same number of scales on September 22 as plot 24, which was treated with parathion at the same dosage. The dieldrin-treated and aldrin-treated plots (27 and 28 , respectively) showed slight increases in soft (brown) scale between the August and September counts, but at no time were the counts in these plots as great as the September counts in the plots treated with parathion or para-oxon. Population counts showed no soft (brown) scale present in the methoxychlor-treated plot (29) or in the untreated (check) plot (34). Populations in the plots treated with TDE (plot 30) DFDT (plot 31), rotenone (plot 32), or DDT (plot 33) were what would be considered normal at the time of the September counts.

SUMMARY.—Although many species of scale that are closely related to soft (brown) scale are effectively controlled by parathion spray treatments, these same treatments bring about conditions causing an increase in numbers of the soft (brown) scale, *Coccus hesperidum* L.

In the present studies high dosages or double applications of parathion tended to result in higher populations of soft (brown) scale than low dosages or single applications. Entomophagous insects reduced the populations of soft (brown) scale that were attributed to parathion treatments, provided no more applications were made.

Low-volume sprays applied with spray-duster equipment caused an increase in populations of soft (brown) scale, but this increase was slight in comparison with the populations found in plots treated with parathion by conventional high-pressure-type equipment. Petroleum oil sprays containing parathion generally resulted in lower populations of soft (brown) scale than did similar sprays without oil.

In comparing multiple-spray-application schedules in which two, four, and six treatments of parthion were applied over a 2-year period, it was found that the greater the number of applications of parathion at the same dosage, the higher the population of soft (brown) scale.

In all the plots treated with organic phosphates there was an increase in populations of soft (brown) scale. Aldrin and dieldrin also caused slight increases of soft (brown) scale, while DDT, three analogues of DDT, and rotenone caused no abnormal increases of this species.

[2] American Cyanamid Co.
[3] American Cyanamid Co.
[4] Victor Chemical Works.
[5] E. I. du Pont de Nemours & Co., Inc.
[6] Julius Hyman & Co.
[7] Julius Hyman & Co.
[8] Rohm & Haas Co.
[9] E. I. du Pont de Nemours & Co., Inc.
[10] Pennsylvania Salt Manufacturing Co.

Table 5.—Effect of one and two applications of organic phosphates and other insecticides on populations of soft (brown) scale on Valencia orange trees in southern California.[1]

PLOT NO.	MATERIAL AND AMOUNT PER 100 GAL. WATER[2]	DATE OF TREATMENT, 1949	AVERAGE NO. OF LIVE SCALES PER UNIT ON DATE OF COUNT		
			10 Leaves (8-22-49)	1-Ft. Terminal[3] (9-22-49)	10 Leaves (11-17-40)
20	Parathion (tech.), 6 oz.	6-10, 8-3	1.5	6.3	2.8
21	Ethyl *p*-nitrophenyl thionobenzenephosphonate (tech.), 6 oz.[4]	6-10, 8-3	1.5	0.5	0.0
22	Para-oxon (tech.), 6 oz.	6-10	2.5	3.0	0.0
23	Parathion (25-W), 1.5 lb.	6-10	0.5	0.1	0.0
24	Parathion (25-W), 2.5 lb.	6-10	0.5	0.3	0.0
25	0,0-dimethyl S-(2-oxo-2 ureidoethyl)dithiophosphate (25-W), 2.5 lb.[5]	6-10	0.0	0.3	0.0
26	S-carbamylmethyl 0,0-dimethyl dithiophosphate (25-W), 2.5 lb.[6]	6-10	0.0	0.3	0.0
27	Dieldrin (25-W), 3 lb.	6-10, 8-3	0.1	0.3	0.0
28	Aldrin (25-W), 3 lb.	6-10, 8-3	0.1	0.2	0.0
29	Methoxychlor (50-W), 1.5 lb. Methoxychlor (50-W), 1.5 lb.; kerosene, 1.5 gal.	6-10 8-3	0.0	0.0	0.0
30	TDE (50-W), 1.5 lb.[7] TDE (50-W), 1.5 lb.; kerosene, 1.5 gal.	6-10 8-3	0.0	0.0+	0.0
31	DFDT (25-W), 1.5 lb.[8] DFDT (25-W), 1.5 lb.; kerosene, 1.5 gal.	6-10 8-3	0.0	0.1	0.0
32	Cube root (4.7% rotenone), 1 lb.; kerosene, 3 gal.; say lecithin, 0.5 lb.	6-10, 8-3	0.0	0.0+	0.0
33	DDT (50-W), 1.5 lb.; kerosene, 1.5 gal.	6-10	0.0	0.0+	0.0
34	Untreated check	—	0.0	0.0	0.0

[1] Spray applied with conventional high-pressure spray equipment at the rate of approximately 3000 gal. per acre.
[2] W = Wettable powder (expressed in percentage).
[3] Approximately 30 leaves.
[4] *EPN*, E. I. du Pont de Nemours & Co., Inc.
[5] *Compound 3901*, American Cyanamid Co.
[6] *Compound 3869*, American Cyanamid Co.
[7] 1,1-Dichloro-2,2-bis-(*para*-chlorophenyl)ethane, (DDD), Rohm & Haas Co.
[8] 1,1,1-Trichloro-2,2-bis-(*para*-fluorophenyl)ethane, Pennsylvania Salt Manufacturing Co.

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IRANIAN LOCUST CONTROL

In connection with a program of technical cooperation with Iran, administered by the Department of State, Mr. William B. Mabee formerly of the Bureau of Entomology and Plant Quarantine, but now with the Office of Foreign Agricultural Relations went to Iran early in April, 1951 as technical advisor of the locust-control mission. The emergency aid extended to Iran included eight small airplanes equipped for distributing sprays, nine pilots, one mechanic and the technical advisor. Over 10 tons of aldrin were flown to Iran and the group sprayed some 53,000 acres. This required 661 flying hours and 625 spraying trips. One gallon of diesel oil was added to each 2 ounces of aldrin and the mixture was applied from the air at the rate of about 1 gallon per acre.

At the end of 4 days the kill, according to Mr. Mabee was 100 per cent. Some 53,700 acres of crops in 18 different localities were saved. Two adult migrating swarms of locusts that had settled for the night were sprayed, with amazingly good results. Some 6630 acres of date palms in eight villages were saved and beneath these palms was a similar number of acres of irrigated tobacco, sugar beets and truck crops. These were saved also. The group received much praise from landowners, peasants and tribesmen for their successful efforts.

Parathion Treatments for the Control of Citricola Scale on Citrus in California[1]

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Citricola scale, *Coccus pseudomagnoliarum* (Kuw.) is a major pest of commercially-grown citrus in California in the warm, semi-arid, interior valleys. Although greatest damage occurs in Tulare, Fresno, and Kern counties in the San Joaquin Valley in central California, heavy infestations also occur in certain localities in Riverside and San Bernardino counties in southern California and in Glenn and Butte counties in the Sacramento Valley in northern California.

Life history studies by Quayle (1915) show that this insect normally has one generation per year although under certain conditions, not well understood, a second generation may occur (Flanders 1942, Woglum 1946). Oviposition begins in late April or early May and is normally completed by the middle of July or early August. The newly hatched, translucent crawlers remain under the adult females a short time before they move to leaves and young terminal growth and begin to feed. During the period from the time of hatching to the following February the scales increase in size only slightly, although they change from the translucent to a dark, mottled, gray color during November and December. With the onset of warm weather, however, during late February and early March their growth rate is greatly increased so that by late April and early May they reach maturity and begin to oviposit.

Damage results from the removal of plant sap by the feeding insects and from copious deposits of scale honeydew, blackened by sooty mold fungus, interfering with the normal functions of the leaves. Heavy scale infestations weaken the trees to such an extent that the yield of fruit is greatly reduced (Woglum 1922).

Although several species of parasites and predators (Compere 1924, Flanders 1942, Scott 1933) are known to attack citricola scale, and may be responsible for a considerable degree of control in some groves (DeBach 1949), they normally do not reduce the scale population to a commercially clean level in California, particularly in the San Joaquin Valley area.

Several insecticide treatments, including hydrogen cyanide fumigation, petroleum oil sprays, lime-sulfur sprays, sulfur dust, and DDT sprays and dusts have been used for the control of citricola scale since it was first recognized as an important pest approximately 40 years ago (Boyce 1949). Since these treatments all have limitations with respect to effectiveness, cost of application, phytotoxicity, or adverse effects on beneficial entomophagous insects and mites, studies have been in progress during recent years to develop information on the use of new insecticides. In these studies parathion has shown outstanding promise for the control of citricola scale and it is the purpose of this report to summarize the results obtained with experimental applications of this insecticide under field conditions during the period from 1947 to 1950, inclusive.

Procedure.—All experiments were conducted in commercial navel or Valencia orange groves in central and southern California, and, in order for the results to be representative of a wide variety of climatic and grove conditions, the various treatments were repeated in a large number of different groves.

The experimental sprays used in these studies contained 25 per cent parathion wettable powder suspended in water and the dusts were composed of 1 and 2 per cent parathion mixed with an inert diluent or with sulfur.

Three types of applications were evaluated: (1) thorough-coverage sprays applied at the rate of 25 to 35 gallons per tree with conventional high pressure spray equipment using manually-operated guns from the ground, and in some groves having large trees also from a tower; (2) low-volume sprays applied with spray-

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[5] *Acknowledgments.*—Thanks are due to R. A. Maddox, C. H. Musgrove, and L. B. Leeson for their assistance in applying materials and taking records, and to R. C. Blinn who was responsible for the chemical estimations of residues.

duster equipment at the rate of 100 to 200 gallons per acre; (3) dusts applied with spray-duster equipment at the rate of 100 pounds per acre. The spray-duster is a multi-nozzled, air-blast type of equipment especially designed to apply dusts or low-volume sprays to citrus trees (Persing & Boyce 1941). Lewis & Landon (1949) have described several types of these machines.

To conform with standard commercial practices, applications were made at three times of the year: (1) late summer and fall (late July to late October) at which time the hatching period was terminated and the scales were translucent and small in size (average length, 1.32 mm.; average width, 0.77 mm.); (2) late winter and early spring (February and early March) when the scales were dark in color and slightly larger (average length, 1.54 mm.; average width, 0.81 mm.) than in late summer and fall; and (3) during the early part of the hatching period (late April to early June) when adult and newly hatched scales were present on the trees.

Treatments were evaluated by standard methods of counting living scales in treated and untreated plots before and at various intervals after applications (Ebeling 1950). Because of distribution characteristics of citricola scale on citrus trees, population levels were determined on leaves during the period from late July to mid-March and on branch terminals 1 foot in length from early April to the middle of May. Only the north sides of trees were sampled as the scale population is normally heaviest on that side.

Parathion residues were quantitatively estimated on fully ripe fruits by the standardized procedures described in detail by Gunther & Blinn (1950). Since parathion has not been recovered from the juice or pulp portions of the fruit (Carman *et al.* 1950) only the residues in the peel are reported in the present investigation.

RESULTS.—A summary of results obtained with parathion treatments in late summer and fall when the scales were translucent and small in size is presented in table 1. The data in this table are average values for treatments repeated 12 to 19 times in different groves. It is apparent that all treatments greatly reduced the number of scales as shown by comparing the pretreatment and post-treatment population levels in the treated and untreated plots. With thorough-coverage, conventional spray applications excellent control was obtained with a dosage of one ounce of actual parathion per 100 gallons, the lowest dosage studied. Low-volume sprays applied with spray-duster equipment at the rate of 100 to 200 gallons per acre gave good control with a dosage of 12 ounces of actual parathion per acre, and excellent control with dosages of 1.5

Table 1.—Control of citricola scale on citrus with parathion treatments applied during late summer and fall (late July to late October).

Type and Rate of Application	Actual Parathion Applied		Living Scales per 10 Leaves		Harvest Residues[1]	
	Per 100 Gallons	Per Acre	Pre-Treatment	Post-Treatment in February	P.p.m. Parathion in Peel of Fruits[2]	
					Navel	Valencia
Thorough-coverage spray applied	1 oz.	—	142	0	—	—
with conventional high-pres-	2 ozs.	—	94	0.04	0.2	0.2
sure equipment at the rate of	4 ozs.	—	176	0	1.1	0.3
25 to 35 gallons per tree[3]	Check	—	102	73	—	—
Low-volume spray applied with	—	12 ozs.	120	0.9	—	0.2
spray-duster equipment at the	—	1.25 lbs.	116	0.1	0.2	0.3
rate of 100 to 200 gallons per	—	1.5 lbs.	109	0.03	0.4	0.03
acre		Check	136	80	—	—
Dust applied at the rate of 100	—	1 lb.	141	8	—	—
pounds per acre	—	2 lbs.	78	2	0.3	—
	—	Check	133	87	—	—

[1] Because of differences in time of maturity the navel oranges were harvested from 1 to 3 months and the Valencia oranges from 6 to 8 months after the applications.
[2] Based on fresh weight of peel.
[3] Approximately 90 trees per acre.

pounds or more per acre. Dust treatments in which parathion was applied at the rate of 1 or 2 pounds actual compound per acre were less effective than comparable dosages applied in low-volume sprays. From a practical standpoint, commercial control of citricola scale with low-volume spray treatments is highly significant since such applications cost from 50 to 80 per cent less than conventional spray and fumigation treatments now in use.

Residues of parathion recovered in the peel of ripe navel and Valencia orange fruits averaged less than 0.5 part per million with dosages which controlled citricola scale.

The unusual susceptibility of small citricola scales in late summer and fall to parathion was demonstrated when it was found that applications not only reduced the scale population in sprayed plots but also reduced them on untreated trees in the near vicinity. Data from single plots in each of three groves showing this type of border effect are presented in table 2. No living scales were found in the treated plots one month after application. Furthermore, it is clearly evident that the population was reduced on untreated trees at least three rows away. This border effect may be due to the combination of (1) drifting of spray during the application and (2) lethal concentrations of parathion vapor moving to the untreated trees from the sprayed plots. Evidence concerning the possible effect of parathion vapor has recently been secured by Carman *et al.*[1] The toxic action of parathion vapor may account for a large part of the effectiveness of low-volume sprays applied with spray-duster equipment where some parts of the trees, particularly the inner portions, are not actually contacted by the sprays.

Another type of border effect which lends support to the possible toxic effect of parathion vapor was observed in certain groves treated with low-volume sprays. It was found in certain groves that relatively poor control was obtained in the tops of all trees and in the tops and lower portions of trees in outside rows bordering roadways or open areas. Poor control at these exposed locations is believed to be the result of air movement preventing the accumulation of lethal concentrations of parathion vapor.

Results with parathion treatments applied in late winter and early spring when the scales were dark in color and slightly larger in size than in late summer and fall are summarized in table 3. The data are average values for treatments repeated 6 to 20 times. All treatments reduced the number of scales in comparison to untreated check plots. Good control was obtained with a thorough-coverage spray application using a dosage of one ounce of actual parathion per 100 gallons of spray. Increasing the dosage to 2 or 4 ounces per 100 gallons of spray did not increase the effectiveness of this type of application. Low-volume spray and dust applications of 1 and 2 pounds of actual parathion per acre were less effective than the thorough-coverage spray treatments.

There were no residue determinations for navel orange fruits following late winter and early spring treatments since the applications were made after the harvest period for this variety was completed. On Valencia oranges an average of 0.4 part per million of parathion was found in the peel following the thorough-coverage spray application of 1 ounce of

[1] Unpublished data.

Table 2.—Border effect on small citricola scales of parathion sprays applied in September, 1947, with conventional spray equipment at the rate of 25 to 35 gallons per tree.

Grove No.	Actual Parathion per 100 Gallons of Water	Living Scales per 100 Leaves						
		Pre-Treatment	Post-Treatment (1 Month After Treatment)					
		Within Plot	Within Plot	Outside of Plot; Rows[1] from Plot				
				1	2	3	4	5
1	4 ozs.	131	0	0.4	4	17	67	—
2	8 ozs.	21	0	0.2	5	8	27	—
3	1 lb.	18	0	0.2	0	1	22	53

[1] 22 to 24 feet between rows.

actual parathion per 100 gallons of water. With the 2- and 4-ounce dosages, averages of 0.7 and 1.3, respectively, were recovered.

No border effect was observed from sprays applied in late winter and early spring as was the case with late summer and fall treatments when the scales were smaller.

Results with treatments applied during the early part of the hatching period when adults and newly hatched scales were present on the trees are summarized in table 4. The data in this table for thorough-coverage sprays are average values for treatments repeated six times and for low-gallonage spray and dust applications, three times. All treatments reduced the scale population in comparison to untreated check plots but only the thorough-coverage sprays gave commercial control.

The effectiveness of thorough-coverage sprays increased as the dosage was increased from 2 to 8 ounces of actual parathion per 100 gallons of water. Increasing the dosage beyond this point was of no benefit. The control obtained with the 2-ounce dosage, however, was not satisfactory from a commercial standpoint.

Single treatments of low-volume sprays applied with spray-duster equipment at the beginning of the hatching period did not give commercial control with a dosage as high as 3 pounds of actual parathion per acre. In a two-treatment program, however, in which the first application was made at the beginning of the hatching period and the second 2 to 4 weeks later good control was obtained with a dosage of 1.5 pounds of actual parathion per acre per application but not with a dosage of 1 pound per acre per application.

Single treatments at the beginning of the hatching period with dusts in which parathion was combined with sulfur did not give commercial control with dosages of 1 and 2 pounds of actual parathion per acre. Double treatments of parathion-sulfur dusts, the first at the beginning of the hatching period, followed by the second 2 to 4 weeks later, were more effective than such dusts containing no sulfur, particularly with the 1-pound dosage of parathion. However, none of the dust treatments gave satisfactory commercial control.

Applications of parathion were not made on Valencia oranges during the period from late April to early June because of proximity to the harvest period for this variety. Therefore, residue values were obtained only from navel oranges. The amounts recovered in the peel of ripe fruits averaged 0.5 part per million with the 2-treatment program of parathion-sulfur dust in which 2 pounds of actual

Table 3.—Control of citricola scale on citrus with parathion treatments applied during late winter and early spring (February and early March).

Type and Rate of Application	Actual Parathion Applied		Living Scales per 10 Leaves		Harvest Residues[1]
	Per 100 Gallons	Per Acre	Pre-Treatment	Post-Treatment in August After Completion of Hatching Period	Av. P.p.m. Parathion in Peel of Valencia Fruits[2]
Thorough-coverage spray applied with conventional high-pressure equipment at rate of 25 to 35 gallons per tree[3]	1 oz.	—	13	3	0.4
	2 ozs.	—	16	6	0.7
	4 ozs.	—	31	4	1.3
	Check	—	24	142	—
Low-volume spray applied with spray-duster equipment at rate of 100 to 200 gallons per acre	—	1 lb.	59	17	—
	—	2 lbs.	88	26	0.1
	—	Check	36	100	—
Dust applied at the rate of 100 pounds per acre	—	1 lb.	88	15	—
	—	2 lbs.	12	30	—
	—	Check	134	281	—

[1] Harvested 3 to 5 months after the applications.
[2] Based on fresh weight of peel.
[3] Approximately 90 trees per acre.

parathion was applied per acre per application. With single treatments of thorough-coverage or low-gallonage sprays the amounts recovered averaged 0.1 to 0.2 part per million.

The occurrence of abnormally high populations of soft (brown) scale, *Coccus hesperidum* L., has been associated with some applications of parathion in citrus groves, apparently the result of the elimination of parasites of this species. Certain information regarding the association of high populations of soft (brown) scale with parathion treatments has been discussed by Elmer *et al.* (1951) and Bartlett & Ewart (1951).

SUMMARY.—Experimental results with parathion treatments applied for the control of citricola scale, *Coccus pseudomagnoliarum* (Kuw.), during the 4-year period from 1947 to 1950, inclusive, are reported.

Three types of applications were evaluated, including, (1) thorough-coverage sprays applied with conventional high-pressure equipment at the rate of 25 to 35 gallons per tree, (2) low-volume sprays applied with spray-duster equipment at the rate of 100 to 200 gallons per acre, and (3) dusts applied with spray-duster equipment at the rate of 100 pounds per acre. To conform with standard commercial practices, applications were made at three times of the year as follows: (1) during late summer and fall (late July to late October) after the termination of the hatching period and the scales were translucent and small in size; (2) during late winter and early spring (February and early March) when the scales were darker in color and slightly larger than in late summer and fall; (3) during the early part of the hatching period (late April to early June) when adults and newly hatched scales were present.

Citricola scale was commercially controlled with all three types of applications during late summer and fall with the thorough-coverage sprays being most effective, followed in order by low-volume sprays and dusts. From a practical standpoint, control with low-volume sprays is highly significant since such treatments cost from 50 to 80 per cent less than present methods of control. With dosages required to control citricola scale, parathion residues recovered in the peel of ripe navel and Valencia fruits averaged less than 0.5 part per million based on the fresh weight of the peel.

The unusual susceptibility of small citricola scales to parathion was demon-

Table 4.—Control of citricola scale with parathion treatments applied during the early part of the hatching period (late April to early June).

Type and Rate of Application	No. of Treatments[2]	Actual Parathion Applied: Per 100 Gallons	Actual Parathion Applied: Per Acre	Av. No. Living Scales: Pre-treatment: Adults per 1 Ft. Branch Terminal	Av. No. Living Scales: Post-treatment: Small Scales per 10 Leaves After Hatching Period	Harvest Residues[3]: Av. P.p.m. Parathion in Peel of Navel Orange Fruits
Thorough-coverage spray applied with conventional high-pressure equipment at rate of 25 to 35 gallons per tree[4]	1	2 ozs.	—	13	10	0.1
	1	4 ozs.	—	21	6	0.2
	1	8 ozs.	—	51	0.5	0.1
	1	1 lb.	—	46	0.5	—
	—	Check	—	23	196	—
Low-volume spray applied with spray-duster equipment at rate of 100 to 200 gallons per acre per application	1	—	1.5 lbs.	41	37	—
	1	—	2 lbs.	34	28	0.1
	1	—	3 lbs.	38	19	—
	2	—	1 lb.[5]	50	25	—
	2	—	1.5 lbs.	37	2	—
Dust applied at rate of 100 lbs. per acre per application	1	—	1 lb. (S)[6]	—	39	—
	1	—	2 lbs. (S)	—	34	—
	2	—	1 lb.	—	177	—
	2	—	1 lb. (S)	—	15	—
	2	—	2 lbs.	—	26	—
	2	—	2 lbs. (S)	—	11	0.5
	—	—	Check	—	280	—

[1] Harvested 7 to 8 months after applications.
[2] Single treatments were applied in late April or early May; in the case of two treatments, the first was applied in late April or early May followed by the second 2 to 4 weeks later.
[3] Based on fresh weight of peel.
[4] Approximately 90 trees per acre.
[5] In the case of two treatments the indicated dosage is for each treatment.
[6] The letter (S) indicates the dust contained 85 per cent sulfur.

strated with late summer and fall treatments which killed scales on untreated trees adjacent to treated areas, apparently the result of the drifting of spray materials at the time of application and the toxic action of parathion vapor.

All three types of applications applied in late winter and early spring reduced the scale population but only the thorough-coverage sprays gave satisfactory commercial control. Parathion residues recovered from the peel of Valencia fruits at harvest averaged 0.4, 0.7 and 1.3 parts per million from plots treated with dosages of 1, 2 and 4 ounces, respectively, of actual parathion per 100 gallons of water applied as thorough-coverage sprays.

During the early part of the hatching period when adult and newly hatched scales were present on the trees, thorough-coverage sprays containing 4 ounces or more of actual parathion per 100 gallons gave satisfactory control. Residues at harvest averaged from 0.1 to 0.2 part per million of parathion in the peel of navel oranges. Single treatments of dusts or low-volume sprays at the beginning of the hatching period reduced the scale population considerably but did not give commercial control. Two treatments of low-volume sprays, the first at the beginning of the hatching period followed by the second 2 to 4 weeks later, with a dosage of 1.5 pounds of actual parathion per acre per application gave good control. Two treatments of dusts applied in a similar schedule greatly reduced the scale population but did not give commercial control. Parathion dusts containing sulfur were more effective than those in which sulfur was not included.

Abnormally high populations of soft (brown) scale, *Coccus hesperidum* L., have occurred in some groves following parathion treatments.

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DR. EDWIN W. KING TO WISCONSIN

Dr. Edwin W. King, formerly with the Illinois Natural History Survey, has accepted an annual appointment as Lecturer and Research Associate in the Department of Entomology, University of Wisconsin. Dr. King received his B.S. from the University of Massachusetts, his M.S. from Virginia Polytechnic Institute, and Ph.D. from the University of Illinois. His duties at Wisconsin will include instruction of a beginning course in general entomology during the summer session and research on the taxonomy and biology of certain forest insect groups, especially in connection with a newly established project grant on the oak wilt disease.

Effects of Insecticidal Fumigants on the Germination of Seed Corn[1]

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In any consideration of fumigants for the control of insects in stored corn (maize) the effect of the insecticide on the viability of the seed is of primary importance. If the fumigant kills the seed outright or so impairs its vitality that death follows, deteriorative changes occur which reduce its value for feeding purposes. Any effects that are revealed in lowered percentage of germination of seed corn or in abnormalities in the developing seedlings obviously lower the value of the seed for planting.

Although the investigation reported here was concerned entirely with seed corn, the results are considered of value in the selection of fumigants for the treatment of stored corn intended for feeding.

Most of the information with regard to the effect of fumigants on the germination of corn has been based on results of a test in which the seed is placed under favorable conditions of temperature and moisture. This test is hereinafter called the warm test. In the official "warm" test (Association of Official Seed Analysts, 1949), the fumigated seed is germinated at temperatures alternating between 68° and 86° F. under standardized conditions. However, an unofficial cold test has been widely adopted as a supplement to the official test by producers of hybrid seed corn. In the latter test the seed is subjected to unfavorably low temperature and high moisture in order to simulate the unfavorable weather conditions which may prevail at planting time.

Since little information has been published on the ability of fumigated corn seed to germinate under the more rigorous conditions of the cold test, plans were made to subject seed fumigated with a number of insecticides to this test. In addition, seed which had been treated with a fungicide (Arasan SF containing 75 per cent tetramethylthiuram disulfide at 0.5 ounce per bushel of seed) after fumigation was submitted to the cold test to determine whether the protection so afforded against detrimental soil organisms would modify the results. A modified warm test made at a constant temperature of 80° F. was applied to all lots of fumigated seed for comparative purposes. It was planned, further, to fumigate hybrid seed corn of two successive crop years, and to test samples from each crop one month or less after fumigation and again after the lapse of a year or more. Any changes that might occur slowly over a long period in the fumigated seed could then be detected.

MATERIAL AND METHODS.—Two lots of seed were available for the tests, one from hybrid plants grown in 1947, the other from a different hybrid grown in 1948. Neither hybrid is now (1951) in commercial production. The moisture content of this seed ranged from 9.4 to 10.2 per cent. The germination tests made within a month after fumigation were completed in the period from February 1 to August 15, 1949; the tests made after prolonged storage of the fumigated seed were made in the interval from January 10 to 20, 1951.

Fourteen fumigants consisting either of single liquid compounds, or of liquid mixtures were applied to seed from both crop years. The compounds were of good commercial grade or better; the mixtures, except for the acrylonitrile-carbon tetrachloride mixture which was a commercial product, were made up in the laboratory.

The seed was fumigated in 5-pound lots, each lot contained in a one-gallon screw-top glass jar, the lid of which was provided with a shellacked cardboard gasket for tight sealing. A small hole in the lid permitted the liquid fumigant to be delivered from a burette directly onto the surface of the seed. After the jar was charged with the required dose of fumigant the hole was stoppered and all seams around the stopper and between the lid and the jar were filled with a melted mixture of beeswax and paraffin. An almost gas-tight seal was thus obtained. All doses were read in mil-

[1] Journal Paper No. J-1928 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 735.

[2] The writer is indebted to the Pioneer Hi-Bred Corn Company for many courtesies including the running of the germination tests; and to Duane Isely, Department of Botany, Iowa State College, for criticisms and suggestions.

Table 1.—Effect of fumigants on the germination of seed corn within one month after treatment.

Fumigant	Crop Year of Seed	Range of Doses Used (Gal. per M Bu.)	Percentage of Seeds Killed at Lowest and Highest Dosage			Dose for 10% Kill of Seed (Gal. per M Bu.)		
			Cold Test	Cold Test +Fungicide	Warm Test	Cold Test	Cold Test +Fungicide	Warm Test
Acrylonitrile	1947	0.5 – 9.5	0—100	2—89	2—76	0.7	0.4	0.7
Acrylonitrile	1948	0.5 – 9.5	8—98	1—89	1—90	0.4	0.6	1.2
Acrylonitrile-carbon tetrachloride mixture (50-50)[1]	1947	1.0 –18.9	9—78	1—63	0—49	0.5	1.1	2.7
	1948	1.0 –18.9	4—76	11—60	0—62	1.3	1.2	4.9
Chloropicrin	1947	0.15– 3.0	6—30	7—26	8—22	1.0	1.6	2.0
Chloropicrin	1948	0.15– 3.0	4—47	0—45	0—42	0.2	0.5	0.6
Chloropicrin-carbon tetrachloride mixture (15-85)[1]	1947	1.5 –20.6	12—46	0—46	1—36	1.5	4.7	5.7
	1948	1.5 –29.6	3—56	0—56	0—55	2.6	3.6	4.6
Ethylene dibromide	1947	0.5 – 9.5	13—34	1—8	0—6	0.3	10.8	13.7
Ethylene dibromide	1948	0.5 – 9.5	2—35	1—16	0—23	0.6	0.7	3.4
Ethylene dibromide-carbon tetrachloride mixture (5-95)[1]	1947	0.7 – 5.9	2—0	0—0	0—0	—	—	—
	1948	0.7 – 5.9	0—0	0—0	0—0	—	—	—
Ethylene dibromide-propylene dichloride-carbon tetrachloride mixture (5-35-60)[1]	1947	0.7 – 5.9	0—3	0—2	0—1	—	—	—
	1948	0.7 – 5.9	2—5	0—1	0—0	—	—	—
Propylene dichloride	1947	1.5 –29.6	2—27	0—14	0—3	(10)	(20)	(70)
Propylene dichloride	1948	1.5 –29.6	0—32	0—12	0—4	(13)	(24)	(70)
Trichloroethylene	1947	1.5 –29.6	0—30	0—17	0—2	8.6	19.2	(70)
Trichloroethylene	1948	1.5 –29.6	8—20	3—18	0—5	13.1	11.3	(30)

Figures in parentheses are extrapolated or otherwise estimated values.
[1] Percentage by volume of ingredients in mixture.

liliters per 5 pounds of seed and were converted to U. S. gallons per 1000 U. S. bushels (based on the 56 pound bushel). Usually two and often three replicate lots of seed were fumigated at each dosage, and generally three or more different doses of each fumigant were applied on different dates to seed of each crop year.

The sealed jars were held in a constant temperature cabinet at 86° F. for a period of 7 days. It is believed that gas-tight sealing for 7 days at this temperature provided conditions that approach the most exacting conditions usually met in practical fumigation.

Since a number of cold-test procedures are in use, a short description is offered of the one followed here. A quantity of soil is inoculated with finely ground fungus-infested corn seed at one quart per bushel of soil. A layer of this soil which has been incubated at 48° F. for several days is spread to a thickness of 0.25 inch on a germination blotter, and 100 seeds are pressed, embryo side down, into the soil. The blotter is supported by a hardware cloth frame and the frame is set in a metal germination tray. Strips of woolen cloth placed between the hardware cloth and the blotter with the ends extending into the water in the germination tray act as wicks to convey moisture to the soil in which the seed rest. The seeds are held at 48° F. and 90 to 95 per cent relative

Table 2.—Effect of time after fumigation on seed corn germination.

Fumigant	Crop Year Seed	Period Between Fumigation and Germin. Tests	Percentage of Seed Killed at 1.5 and 29.6 Gal./M Bu.			Dose for 10% Kill of Seed (Gal./M Bu.)		
			Cold Test	Cold Test+ Fungicide	Warm Test	Cold Test	Cold Test+ Fungicide	Warm Test
Carbon disulfide	1947	1 mo.	5—40	0—24	0—12	1.6	4.3	20.2
Carbon disulfide	1947	1.5–2 yrs.	6—91	0—82	0—43	1.0	2.1	7.8
Carbon disulfide	1948	1 mo.	6—49	0—38	0—30	2.4	8.9	12.4
Carbon disulfide	1948	1.5–2 yrs.	5—86	0—68	1—31	1.7	3.7	10.5
Carbon disulfide-carbon tetrachloride mixture (20-80[1])	1947	1 mo.	0—3	0—25	0—6	(70)	(15)	(50)
	1947	1.5–2 yrs.	0—54	0—48	1—13	(8)	(8)	(20)
Carbon disulfide-carbon tetrachloride mixture (20–80[1])	1948	1 mo.	0—12	0—18	0—4	(26)	(21)	(50)
	1948	1.5–2 yrs.	0—42	1—44	0—8	(10)	(10)	(40)
Carbon tetrachloride	1947	1 mo.	0—4	0—16	0—6	(30)	16.5	(30)
Carbon tetrachloride	1947	1.5–2 yrs.	0—16	3—35	0—4	20.9	12.6	(50)
Carbon tetrachloride	1948	1 mo.	0—8	0—14	0—3	(30)	19.0	(70)
Carbon tetrachloride	1948	1.5–2 yrs.	0—32	1—31	2—5	20.1	11.0	(70)
Ethylene dichloride	1947	1 mo.	0—0	1—8	1—4	(70)	35.0	(70)
Ethylene dichloride	1947	1.5–2 yrs.	2—41	0—25	0—4	5.0	14.5	(50)
Ethylene dichloride	1948	1 mo.	0—16	0—8	0—4	16.8	(50)	(70)
Ethylene dichloride	1948	1.5–2 yrs.	0—33	5—20	2—2	9.1	17.5	(70)
Ethylene dichloride-carbon tetrachloride mixture (75-25)[1]	1947	1 mo.	4—11	3—12	0—4	(30)	27.4	(50)
	1947	1.5–2 yrs.	3—49	3—31	0—5	8.7	10.0	(50)
Ethylene dichloride-carbon tetrachloride mixture (75-25)[1]	1948	1 mo.	11—12	1—10	0—3	(30)	(30)	(70)
	1948	1.5–2 yrs.	8—40	7—28	0—5	10.5	17.4	(50)

Figures in parentheses are extrapolated or otherwise estimated values.
[1] Percentage by volume of ingredients in mixture.

Table 3.—Percentage of germination of the untreated (control) seed.

Crop Year	Period from Initiation of Exp. to Germination Test	Cold Test			Cold Test+Fungicide			Warm Test		
		Range	Mean	b[1]	Range	Mean	b[1]	Range	Mean	b[1]
1947	1 mo.	35–70	55.2	−0.0913	88–96	91.9	−0.0122	98–100	99.1	+0.0047
1947	1.5–2 yrs.	64–89	77.9	−0.0465	87–96	91.8	+0.0097	93– 97	95.4	−0.0031
1948	1 mo.	27–43	36.6	+0.0341	56–82	71.7	+0.0647	96– 99	98.0	+0.0098
1948	1.5–2 yrs.	46–70	55.7	−0.0089	81–91	86.7	+0.0080	95– 98	96.6	−0.0068

[1] Slopes of the regression lines.

air humidity for 8 days after which they are transferred to a standard germination cabinet at 80° F. where the viable seeds germinate in 3 to 4 days. Seedlings which have developed primary and secondary roots and a clean, white plumule are considered normal. The same procedure was followed in testing the seed, which, after fumigation, was treated with the fungicide. Eight to 12 samples of 100 seeds with and without fungicide treatment were subjected to the cold test and five samples of 100 seeds were subjected to the modified warm test from each fumigated lot of corn.

RESULTS.—The results are given in tables 1 and 2 which detail for each fumigant, crop year, and germination test the lowest and highest doses applied, the corrected percentages of seed killed (100 minus the percentage of seed germinated) at these doses, and the doses for 10 per cent kill (LD_{10}) of seed.

The corrected percentages of seed killed were calculated by the usual formula, $C=x-y(100)/100-y$, in which x is the percentage of dead seed (and/or abnormal seedlings) in the fumigated sample and y the percentage of dead seed (abnormal seedlings or both) in the corresponding control sample.

The data for the untreated (control) seed are summarized in table 3. Variability in both crop years is most marked in the cold-test data, is definitely smaller in the data from application of the cold test after fungicide treatment (cold test+fungicide) and still smaller in the warm test data. Variability between crop years is also greatest in the cold test data though the 1947 seed consistently show higher mean percentages of germination than the 1948 seed. Again, the warm test data show small differences. Age of the seed after initiation of the experiment had a significantly greater effect on germination under cold test conditions than under the conditions of the other tests; the cold test +fungicide data and the warm test data showed decreasing differences in the order given.

To determine whether there were significant trends in the percentage germination of the control seed within the experimental period, regression lines were calculated from percentage of germination as y and time in days within the experimental period as x. The slopes (b) of these lines (table 3) are small and point to no significant trends.

The LD_{10} values were obtained by probit analysis (Finney 1947), or by graphic analysis of the experimental data. The 10 per cent level of seed kill was chosen because it is believed to be as low a point as can be determined with reasonable accuracy by the probit method yet high enough to indicate any marked adverse effect of the fumigant on the seed.

DISCUSSION.—These fumigants fall into three rather well-defined groups according to their safety for the treatment of seed corn. The first group (table 1) contains the highly deterimental fumigants-acrylonitrile, the acrylonitrile-carbon tetrachloride mixture, chloropicrin, the chloropicrin-carbon tetrachloride mixture, and ethylene dibromide. The detrimental effects produced by these fumigants were so marked within one month after treatment that germination of the older fumigated seed was not tested. No effective insecticidal dosage of any of these fumigants can be used without considerable risk of injury to germination.

The second group (Table 2), of marginal safety, contains only carbon disulfide, which, owing to its inflammability, is now seldom used except in mixtures for the fumigation of grain. The lowest safe dose of carbon disulfide, between 1 and 2 gal-

lons per 1000 bushels as indicated by the cold test, is close to the minimum for effective control of corn-infesting insects. The warm test proved much less critical than the cold test and less critical than the cold test after fungicide treatment for evaluating the safeness of carbon disulfide for seed-corn fumigation.

The third group (Tables 1 and 2) contains the materials which appear relatively safe to use on seed corn, namely propylene dichloride, trichloroethylene, the carbon disulfide-carbon tetrachloride mixture, carbon tetrachloride, ethylene dichloride, and the ethylene dichloride-carbon tetrachloride mixture. All of these fumigants except propylene dichloride and trichloroethylene were tested for percentage germination within one month and again within 1.5 and 2 years after fumigation. The loss of viability was always greater under cold test and cold test plus fungicide conditions after the longer post-fumigation period. The warm test gave less decisive results.

These fumigants can be applied to seed corn at doses up to about 10 gallons per 1000 bushels without material reduction in germination as determined by the cold test and cold test plus fungicide. Ethylene dichloride which fell definitely below this level in one series of tests is, owing to its inflammability, scarcely ever used alone in grain fumigation.

The two mixtures which contained 5 per cent ethylene dibromide did not affect germination at 5.9 gallons per 1000 bushels in tests made up to one month after fumigation; older fumigated seed was not tested. The results suggest, however, that such ethylene dibromide mixtures can be used at effective insecticidal dosage without important reduction in seed viability. Mixtures containing much larger proportions of ethylene dibromide would probably be detrimental.

The information furnished by the cold test on seed untreated or treated with fungicide points to a narrower margin of safety, even for the relatively safe fumigants, than previously supposed. It emphasizes the need for careful selection of dosage and exposure time, and for adequate removal of the fumigant after fumigation. While details still remain to be worked out, it is probable that for a dosage of 6 gallons per 1000 bushels, an exposure of 3 to 5 days in less than gas-tight enclosures would not be excessive for carbon tetrachloride, the carbon disulfide-carbon tetrachloride mixture, and the ethylene dichloride-carbon tetrachloride mixture. At the end of this period, the seed should be thoroughly aerated to remove the residual fumigant vapor. In general, the longest exposure time consistent with safety to seed germination will give the greatest insecticidal efficiency.

Comparison of the LD_{10} values for crop years and post-fumigation periods (estimated values are omitted) shows that within a post-fumigation period crop year is associated generally with small actual differences in LD_{10} which reveal no markedly consistent trend; but within crop years the LD_{10} values are always smaller for the longer post-fumigation period. It is believed, therefore, that age before fumigation is of less importance in seed viability than age after fumigation.

SUMMARY.—Hybrid seed corn produced in two different crop years was fumigated for 7 days at 86° F. with fourteen fumigants. The seed was then tested for percentage of germination within one month after fumigation and some of it again after 1.5 to 2 years of storage, The germination tests included the cold test, cold test after treating the fumigated seed with a fungicide (tetramethylthiuram disulfide), and a modification of the official warm test.

The results of these tests place the fumigants in three groups: (1) Fumigants highly detrimental to germination—acrylonitrile, acrylontrile-carbon tetrachloride mixture (50-50), chloropicrin, chloropicrin-carbon tetrachloride mixture (15–85), and ethylene dibromide; (2) a marginal group which contains only carbon disulfide; (3) a relatively safe group—propylene dichloride, trichloroethylene, carbon disulfide-carbon tetrachloride mixture (20–80), carbon tetrachloride, ethylene dichloride, and ethylene dichloride-carbon tetrachloride mixture (75–25). The safer fumigants can be used at doses up to about 10 gallons per 1000 bushels of seed; however, exposure time and removal of residual fumigant vapor after treatment are important in protecting seed viability. For the carbon disulfide mixture, carbon tetrachloride, and the ethylene dichloride mixture at a dosage of 6 gallons per 1000 bushels, an exposure of 3 to 5 days and aeration of the seed after fumigation are suggested.

Limited tests indicate that mixtures which contain 5 per cent ethylene dibromide are safe to use up to about 6 gallons per 1000 bushels of seed corn.

Age of seed corn before fumigation is probably of less importance for seed viability than age after fumigation.

The cold test applied to fumigated seed either untreated or treated with a fungicide is more selective than the warm test in revealing deterimental effects of fumigants on germination.

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Aerosol Tests Against the Oriental Fruit Fly and Other Insects

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The introduction of the oriental fruit fly, *Dacus dorsalis* Hendel, into the Hawaiian Islands during World War II again emphasized the hazard of insect transportation brought about by modern developments of intercontinental airplane traffic (Cooley 1947). This insect now constitutes a serious threat to agriculture in other areas, especially the fruit industries in California (Armitage 1949).

Early in 1948 the authors tested the efficiency of various Freon-propelled aerosols against the oriental fruit fly as well as other insects occurring in the Hawaiian Islands. Information was desired on the fly's resistance to the aerosol formulation then in use, and to other experimental formulas, in disinsectizing aircraft departing for the mainland United States. The results of these tests are presented in this paper.

As early as September 1946 the aerosol treatment of departing aircraft was supervised by quarantine officers of the Bureau of Entomology and Plant Quarantine in Hawaii. The aerosol used was the *G-382* formula, containing 1 per cent of pyrethrins and 3 per cent of DDT developed by Bureau workers at Beltsville, Maryland, for use by the U. S. Public Health Service. Prior to that time a formula containing 2 per cent of pyrethrins had been used on commercial aircraft (Dunnahoo 1943) for controlling insects of public health importance.

The notice of the adoption and method of use of *G-382* was given in the Federal Register for September 2, 1948. At the prescribed dosage of 5 grams per 1000 cubic feet this aerosol was found to be highly effective against house flies, *Musca domestica* L., and always gave 100 per cent mortality of *Anopheles quadrimaculatus* and *Aëdes aegypti* mosquitoes.

The work with the oriental fruit fly required a large supply of test insects. At first they were trapped in the field with oil of citronella as bait. However, nearly all the flies caught were males. A better supply of both sexes was obtained by bringing heavily infested bananas into the laboratory. From 25 to 30 adults were reared from one banana. Some insects were also reared in the fruit of the guava.

The testing room used at first had a volume of 787 cubic feet and was located in the end of a greenhouse. It had composition walls and ceiling and a concrete floor covered with paper. In later tests a standard Peet-Grady chamber was used.

The aerosols tested, the formulations of

Table 1.—Aerosol formulas tested against the oriental fruit fly.

(Figures in per cent.)

MATERIAL	G-382	G-421	G-500	G-559	G-567
Pyrethrum extract (20%)	5	5	5	5	5
DDT	3	3	3	3	3
Benzene hexachloride, gamma isomer	—	—	3	—	—
Piperonyl butoxide	—	8	8	4	2
Cyclohexanone	5	7	10	5	5
Lubricating oil	2	—	—	—	1
Methyl salicylate	—	—	—	—	0.25
Freon-12	85	77	71	83	83.75

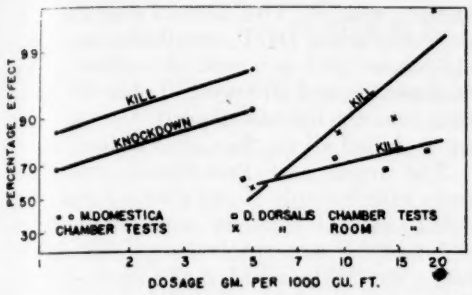

FIG. 1.—Tests with the *G-382* aerosol against house flies and oriental fruit flies.

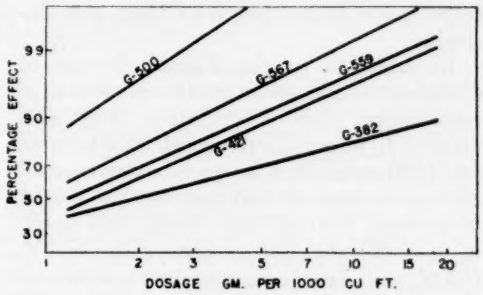

FIG. 2.—Tests with various aerosol formulas against the oriental fruit fly in a Peet-Grady chamber.

which are shown in table 1, were either shipped from Beltsville or prepared in Honolulu from concentrates brought from Beltsville. They were delivered into the testing rooms by a laboratory dispenser such as has been described by McGovran *et al.* (1943) and Goodhue *et al.* (1946).

Table 2.—Particle size data for aerosol formulas tested.

FORMULA	NON-VOLATILE CONTENT (PER CENT)	MEAN MASS DIAMETER (MICRONS)	DIAMETER OF LARGEST PARTICLE (MICRONS)
G-382	15	14	45
G-421	23	25	70
G-500	29	30	70
G-559	17	31	90
G-567	16.25	22	70

Before the effectiveness of the newer formulas could be measured, it was necessary to determine the resistance of the oriental fruit fly to formula *G-382*. It was also desirable to determine the relative resistance of the sexes to this formulation. At a dosage of 0.95 gram per 1000 cubic feet, 62 per cent of males and 63 per cent of females were knocked down, and kills of 62 and 64 per cent after 1 and 2 days were obtained on the males and 64 and 68 per cent on the females.

Although these tests showed that better performance than that obtained with *G-382* is possible, the formulas tried have since been proved unsuitable for use in aircraft because of odor, irritation, and an excessively high nonvolatile content that would leave objectionable residues.

In room tests it was found that all the new formulas were more effective than *G-382* against the oriental fruit fly. The results of similar comparisons in a Peet-Grady chamber are given in figure 2. Tests with some of these formulas against other insects have been reported by McBride & Sullivan (1950).

In other room tests with the *G-382* aerosol at dosages up to 19.05 grams per 1000 cubic feet, the oriental fruit fly was considerably more resistant than the house fly. Later in Peet-Grady tests even greater differences were shown (fig. 1).

Table 4.—Mortality of *Dacus dorsalis* exposed to glass surfaces treated with a DDT residual aerosol.

APPROXIMATE DEPOSIT OF DDT (Mg. per Sq. Ft.)	PER CENT KILL AFTER— 1 Day	2 Days
150	98	100
300	98	100
450	100	—

Moreover, the particle-size data for these formulas, obtained by A. H. Yeomans of this Bureau and given in table 2 show that formulas *G-421*, *G-500*, and

Table 3.—Per cent mortality of certain insects after exposure to three aerosol formulas at a dosage of 20 grams per 1000 cubic feet.

SPECIES	G-382 1 Day	G-382 2 Days	G-382 3 Days	G-421 1 Day	G-421 2 Days	G-421 3 Days	G-500 1 Day
Alphitobius piceus	60	60	66	86	93	93	100
Ammophorus insularis	27	33	33	80	80	86	100
Pycnoscelus surinamensis	80	93	100	80	86	86	100

G-567 gave larger particles than was desirable.

In addition to the 5-gram dosage of *G-382* that was used in the presence of passengers, this formulation was also applied to unoccupied aircraft at 20 grams per 1000 cubic feet, to give better control of various hard-to-kill insects that might be present. Tests at this dosage were made in a 787-cubic-foot room with *G-382*, *G-421*, and *G-500* against two species of Coleoptera, *Alphitobius piceus* (Oliv.) and *Ammophorus insularis* Boh., as well as large nymphs of the Surinam roach *Pycnoscelus surinamensis* (L.). The results of these tests, shown in table 3, indicate that *G-382* is less effective than either of the other two formulas.

In other tests oriental fruit flies were exposed to glass panes that had been treated with a DDT aerosol designed to leave a residue. This aerosol contained 5 per cent each of DDT, cyclohexanone, and chlordane, 32.5 per cent of acetone, and 52.5 per cent of *Freon-12*. Table 4 shows that even the lightest deposit, 150 mg. per sq. ft. killed all the flies after 2 days.

The room and Peet-Grady chamber tests with formula *G-382* showed that the adult oriental fruit fly was much more resistant to this aerosol than was the adult house fly. Males and females showed similar resistance. Tests with Coleoptera and the Surinam roach indicated that more toxic formulas than the currently used *G-382* aerosol are needed to control the more resistant agricultural and other types of insects on aircraft. Tests with residual applications of a DDT aerosol showed that a DDT residue might under certain conditions be effective against the oriental fruit fly.

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SCIENTIFIC NOTES

The Names of the Field and House Crickets

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Recent studies that have a bearing on the scientific names of the field cricket, *Acheta assimilis* F., and the house cricket, *A. domesticus* L., merit the attention of workers in applied entomology. For many years the field cricket was almost universally known as *Gryllus assimilis*, and the house cricket was placed in the same genus and called *G. domesticus*. There has been a growing tendency to treat both species as belonging to a genus distinct from *Gryllus* in a strict sense (type *G. campestris* L. of the Old World). This tendency has been noted especially among European entomologists concerned with the generic separation of *Acheta domesticus* form *campestris* and its allies. The Linnaean name *Acheta* 1758 was believed to be unavailable, because Opinion 124, International Commission on Zoological Nomenclature, 1936, declared invalid this and other names used by Linnaeus apparently in a subgeneric sense. Believing that a new generic name was needed for *domesticus*, Uvarov[1] proposed *Gryllulus* (type *G. domesticus* L.), and that name had fairly wide acceptance, in combination with both *assimilis* and *domesticus*, until Roberts[2] pointed out that *Acheta* F. 1775 was available, with *domesticus* the type, and that it had priority. *Gryllulus* Uv. thus is a synonym of *Acheta* F.

This disclosure by Roberts has led to the placing of *Acheta domesticus* and *A. assimilis* on the list of common names.[3] There have been unfortunate misunderstandings of the situation, however, such as La Rivers' use of the family name Achetidae[4] and Tinkham's adoption of Gryllulidae.[5] Regardless of the narrowing of generic limits for *Gryllus*, that genus has remained valid, is in constant use for Old World species, and is the basis for the name Gryllidae. A proposal to the International Commission to place *Acheta* F. 1775, with *G. domesticus* L. 1758 type, on the Official List of Generic Names in Zoology has recently been announced.[6]

About a generation ago it was customary to recognize several Nearctic species of *Gryllus* (now to be known as *Acheta*). Overlapping of taxonomic characters of the forms and the consequent difficulty, if not impossibility, of supplying satisfactory identifications led Rehn & Hebard[7] to recognize only two New World species, then known as *G. assimilis* and *G. domesticus*. They did suggest, however, that a more precise reference to the character of various populations of *assimilis* might be indicated by using symbols. The identification of all American field crickets of this genus as *assimilis* has been extremely convenient, though there has been reason to suspect that subspecies or other segregates existed[8] and that the determinations made in a broad sense were not so adequate as was desirable.

B. B. Fulton, whose penetrating studies of the cricket genera *Nemobius* and *Oecanthus* are classics, has recently published an abstract[9] of work with *Acheta* whereby he recognizes four races of *assimilis* which occur in North Carolina. They are distinguished by physiological characters, such as song, choice of habitat, or seasonal history. Mating of different races has occurred under artificial conditions, with resulting eggs that did not hatch, suggesting that there is an internal isolating mechanism in addition to the features previously mentioned. These races are not satisfactorily separated by the usual taxonomic characters of a morphological nature, and since names have not yet been applied to them, it is advisable to continue using, for the present, the name *Acheta assimilis* in a broad sense. We can only guess at the number of subspecies or species of the *assimilis* complex that may occur in the United States, some recognizable in collections and others distinguishable only by a keen observer in the field. In addition to the far-reaching implications that Dr. Fulton's work has for taxonomists and geneticists, students using field crickets as test animals in insecticidal or life history studies will do well to appreciate that populations from different areas or ecological habitats are far from uniform.

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[4] Amer. Midl. Nat. **39**: 709, 1948.
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The study by Cantrall in particular is recommended.
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Experimental Control of Sycamore Scale with Combinations of Oil and Certain Synthetic Organic Insecticides

LELAND R. BROWN[1] and CLARK O. EADS[2]

Of the several defoliating factors of sycamore (*Platanus* spp.) in southern California, the sycamore scale[3] is one of the most important. The young scale inserts its rostralis into the lower surface of the leaf blade, the midrib or petiole, which results in necrosis of the surrounding tissue. A severely infested leaf may be completely covered with these minute dead spots. This injury usually results in a premature dropping of the leaves. Some municipalities, with many sycamores, maintain street crews to remove fallen leaves which result from injuries of this insect (Smith 1944).

The sycamore scale has three generations per year. The eggs are laid beneath the bark plates of the trunk and limbs, and upon hatching the young scales migrate to the leaves. There the insects mature and then return to the trunk and limbs to lay eggs. In late January the young insects become active and it is against this stage which control measures are most effective (Smith 1944). The control measure most commonly used is the application of 3 gallons of a dormant oil per 100 gallons of water, with emphasis on depositing the spray beneath the bark plates of the trunk and limbs (Essig & Hoskins 1944). Foliage treatments usually are ineffective be-

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[2] Senior Laboratory Technician, Univ. of California at Los Angeles.
[3] *Stomacoccus platani* Ferris, Homoptera, Margarodidae.

cause of the difficulty of wetting the scale beneath the mass of leaf hairs.

PURPOSE OF EXPERIMENT.—It was desirable to find more effective control measures for the sycamore scale. Little has been published on the control of this insect since Smith's work (1944), particularly with reference to insecticides developed during and after World War II. Pritchard & Beer (1950) found that toxaphene (formulated as an emulsion) in combination with an oil gave excellent control of an unarmored scale. The results, reported by these authors, suggested the possibility of obtaining better control of the sycamore scale, an unarmored scale, with various combinations of oil and some of the new synthetic organic insecticides.

Another important defoliating factor of the sycamore is a disease, the sycamore leaf and twig blight, caused by the fungus, *Gnomonia venata*. It is common practice to include a fungicide, usually bordeaux, in the dormant application for control of the blight. It was desirable that a more effective fungicide be found for the control of this disease. Thus, several experimental fungicides were included in the various treatments of the following experiment.[4]

EXPERIMENTAL METHODS.—In January, 1950, the Los Angeles Department of Recreation and Parks made available to the authors a nursery plot of 285 native sycamores, *Platanus racemosa*, in the Hansen Dam area of Los Angeles. The sizes of these trees were quite variable; the average tree height was about 8 feet. Twelve treatments and an untreated check were randomized within each of four replicates, making a total of 52 plots. Insecticide and fungicide treatments applied are listed in table 1. All treatments, except the 1.5 per cent oil treatment, were applied on February 3; the latter treatment was applied on February 4. Applications were made with a conventional high pressure sprayer applying an average of 1.2 gallons of spray per tree.

By May 10, 1950, the trees were in full foliage. Samples of 100 leaves per plot were taken on this date by picking approximately equal numbers of leaves from each tree in the plot. All leaves were taken at random from the lower periphery of each tree at a height of about 5 feet. Each 100-leaf sample was placed in a paper sack and held at 40° F. until counts were made. Two methods of injury notation were used: (1) numbers of scale injuries, or spots, per 100-leaf sample, and (2) per cent of injured leaves. In the latter category, a leaf was counted as injured if it had one or more injuries. The two series of injury data, obtained by each method of injury notation, were subjected to analyses of variance. Injury means of each treatment and the least significant difference between injury means are presented in table 1.

RESULTS.—The data indicate that, of the two methods of injury notation used, per cent injured leaves was more sensitive to differences between treatments. Also this method of notation was much more rapid. Of the insecticides tried, 2 pounds of a 25 per cent wettable powder of parathion per 100 gallons of water gave the best control of scale injury, whether used alone or with 1.5 gallons of a light-medium oil. Wettable powders of toxaphene (40 per cent), DDT (50 per cent) and benzene hexachloride (25 per cent), each used at the rate of 1 pound of active ingredient per 100 gallons and with 1.5 gallons of a light medium-oil, were better than the standard of 3 gallons of a light-medium oil per 100 gallons. But without oil, wettable powders of DDT and benzene hexachloride were almost as poor as the untreated check, while toxaphene wettable powder was about equivalent to the standard. The control was about the same with 2.5 pounds per 100 gallons of a 40 per cent wettable powder of chlordane alone or in combination with 1.5 gallons of a light-medium oil, and both treatments were almost equivalent to the standard 3 per cent oil.

Table 1.—Experimental treatments, applied in the dormant season, for the control of the sycamore scale, and notation of scale injury on the foliage.

DORMANT TREATMENT[1]		SCALE INJURY NOTATION[9]	
Insecticide	Amt. per 100 Gal.	Injuries per 100 Leaves	Per Cent Injured Leaves
Oil, lt. med.[2]	3 gal.	561	68
BHC, 25% WP[3]	4 lbs.	3309	90
BHC, 25% WP[2] Oil, lt. med.[4]	4 lbs. 1.5 gal.	238	41
Chlordane 40% WP[5]	2.5 lbs.	964	59
Chlordane 40%, WP[5] Oil, lt. med.[4]	2.5 lbs. 1.5 gal.	528	58
DDT, 50% WP[6]	2 lbs.	3480	86
DDT, 50% WP[3] Oil, lt. med.[4]	2 lbs. 1.5 gal.	154	41
Parathion, 25% WP[7]	2 lbs.	21	16
Parathion, 25% WP[7] Oil, lt. med.[4]	2 lbs. 1.5 gals.	22	17
Toxaphene, 40% WP[8]	2.5 lbs.	989	71
Toxaphene, 40% WP[8] Oil, lt. med.[4]	2.5 lbs. 1.5 gal.	273	38
Oil, lt. med.[4]	1.5 gal.	282	47
Check, no treatment		5523	93
Least significant difference:	19:1— 99:1—	1140 1529	20 27

[1] Trees (*Platanus racemosa*) sprayed 2/3 & 4/50. Hansen Dam, Los Angeles, Calif.
[2] Tank mix with bordeaux as the emulsifier.
[3] A wettable powder, Stauffer Chemical Co.
[4] Tank mix, blood albumen as emulsifier at the rate of 4 oz. per 100 gallons.
[5] Dow Chemical Co.
[6] Stauffer Chemical Co.
[7] California Spray-Chemical Corp.
[8] Toxaphene 40% Spray Powder, Chipman Chemical Co.
[9] Leaves sampled 5/10/50.

An apparent discrepancy will be noted by comparing the injury means of the 3 per cent oil and the 1.5 per cent oil, that is, the 3 per cent oil was significantly inferior to the 1.5 per cent oil. A possible explanation of this might be the effects on the emulsion of the fungicide, bordeaux, as has been suggested by deOng (1948, p. 142). This author suggests that an emulsion, formed with bordeaux mixture, is quite stable, or "tight," and also that the lime may combine with part of the oil to reduce the effectiveness of the spray. The effects of the lime and decreased deposit (as a result of run-off of the stable emulsion) possibly may have reduced the effectiveness of the 3 per cent oil treatment to less than that of the 1.5 per cent oil treatment.

CONCLUSIONS.—Where conditions of safety and

[4] Pierre A. Miller, of the Division of Plant Pathology, Univ. of California at Los Angeles, cooperated in this experiment in all matters concerning the experimental fungicides and their use. Professor Miller will report elsewhere the results of the fungicide tests.

use permit, such as might be the case in nurseries, 2 pounds of a 25 per cent wettable powder of parathion, per 100 gallons of water, may be used for sycamore scale control in late January or early February. For street, roadside and home plantings of sycamores, a relatively safe and effective spray that might be used, in preference to the commonly recommended 3 per cent oil, would be a dormant spray of a wettable powder of toxaphene, DDT or benzene hexachloride, each used at the rate of 1 pound of active ingredient per 100 gallons of water, and each in combination with 1.5 gallons of a light-medium oil.

SUMMARY.—An experiment, on the control of the sycamore scale in the dormant season, is described. Samples of leaves, injured by the scale, were collected in the foliage season. Sprays of parathion wettable powders, alone or with 1.5 per cent light-medium oil, were equally effective and were the best treatments tried. Wettable powders of toxaphene, DDT and benzene hexachloride, each with 1.5 per cent light-medium oil, were superior to the standard treatment of 3 per cent light-medium oil, but without oil they were generally inferior to the standard. Chlordane wettable powder sprays, alone or with 1.5 per cent light-medium oil, were equivalent to the standard 3 per cent light-medium oil. Of the two methods of injury notation used—number of scale injuries per 100 leaves, and the per cent of injured leaves—the latter was more rapid and more sensitive to differences between treatments.

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Insecticide Tests against the Potato Tuberworm[1]

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The literature on the control of the tuberworm in stored potatoes is rather extensive. In recent years, Helson (1942) has reported promising results with an inert mineral dust (magnesite), and Walker & Anderson (1944) with 2 per cent DDT dust. Hofmaster & Anderson (1948) prevented infestation in tubers with DDT-impregnated bags.

In the work reported here, three methods of protection were attempted: dusting of tubers, storage of tubers in boxes sprayed on the inside, and storage in impregnated bags. Gallon jars were used as containers for all tests except those with treated boxes. Moths were introduced in some series as adults and in others during the cocoon stage. Adults were allowed to remain together in small bottles long enough for mating to take place before introduction to tests. In the cocoon-introduction series, approximately 50 cocoons were placed in each test container, and for adult introduction. moths from about 50 cocoons were used. In order to test the residual value of the insecticides, introductions were made to the same test containers in most series more than once at intervals of a month or more, after treatments had been applied only once. Different check lots for each introduction were prepared at the same time as the treated lots.

DUST TESTS.—Dust tests were carried out with cocoon and adult introductions and with potatoes dusted after exposure to oviposition. In the first adult-introduction series, which was not replicated, plain pyrophyllite; 1 and 3 per cent DDT, chlordane, toxaphene, gamma benzene hexachloride, and methoxychlor dusts all prevented infestation completely at first. After the second introduction a month later the lots treated with 1 per cent toxaphene, and 3 per cent DDT and methoxychlor became lightly infested. Checks became heavily infested both times.

In the second adult-introduction series, all the insecticide dusts at one per cent and plain pyrophyllite were used. Tests were replicated three times. The one introduction resulted in no infestation in any treated lot, while all three checks became infested with more than 300 tunnels in all.

The cocoon-introduction dust series was identical with the last adult-introduction series except in method and number of introductions. Introductions were made twice. Results are given in table 1. Jars of potatoes which became infested as a result of the first introduction did not receive cocoons at the second introduction.

In the fourth dust series potatoes were exposed to oviposition for 24 hours before dusting. All those used bore at least five eggs. Treatments and replications were the same as in the previous two series. All treated lots remained free of infestation. The three checks became infested with 38 tunnels.

TREATED BOX TESTS.—The object of these tests was to simulate, on a small scale, the spraying of storage rooms and houses. Potato tubers were stored with moth populations in corrugated cardboard boxes sprayed on the inside with three per cent solutions of DDT, chlordane, toxaphene, and gamma benzene hexachloride in xylene. One adult-

Table 1.—Infestation of dusted potatoes resulting from introduction of tuberworm cocoons; three replications; two introductions.

TREATMENTS	INFESTATION FOLLOWING INTRODUCTION OF COCOONS ON THE DATES LISTED			
	Mar. 24		Apr. 22	
	Jars Infested (of 3)	Total Tunnels (in 9 tubers)	Jars Infested[1]	Total Tunnels
1% DDT	2	4	0	0
1% Chlordane	1	3	0	0
1% Toxaphene	0	0	0	0
1% γ benzene hexachloride	0	0	0	0
1% Methoxychlor	1	4	0	0
Pyrophyllite	1	4	0	0
1st Checks	3	200+	(no introduction)	
2nd Checks	(no introduction)		3	300+

[1] Number of jars used for second introduction: one with DDT; two each with chlordane, methoxychlor, and pyrophyllite; and three with each of other treatments.

[1] *Gnorimoschema operculella* Zell.; Paper No. A319, Contribution No. 2279 of the Maryland Agricultural Experiment Station (Dept. of Entomology).

Table 2.—Infestation of potato tubers in treated boxes resulting from introduction of adult tuberworms; three replications; three introductions.

Treatment	Infestation Following Moth Introduction on the Dates Listed					
	Feb. 10		Mar. 18		Apr. 19	
	Boxes Infested (of 3)	Total Tunnels (in 9 tubers)	Boxes Infested (of 3)	Total Tunnels (in 9 tubers)	Boxes Infested (of 3)	Total Tunnels (in 9 tubers)
3% DDT	3	8	2	2	0	0
3% Chlordane	0	0	0	0	0	0
3% Toxaphene	1	5	1	1	0	0
3% γ benzene hexachloride	0	0	0	0	0	0
Checks	3	no count	3	24	1	1

introduction and one cocoon-introduction series were used. In each series, treatments were replicated three times. Potatoes were replaced in all boxes before each introduction. Results of the adult-introduction tests are given in table 2.

In the other box series, cocoons were introduced twice at an interval of a month. There was no infestation in treated boxes after the first introduction. Two of the three check lots became infested with 33 tunnels. After the second introduction, the tubers in one toxaphene-treated box became infested with two tunnels. Only one check lot became infested with six tunnels.

Impregnated Bag Test.—In this series, tubers in small burlap bags treated with one-half and one per cent xylene solutions of DDT, chlordane, toxaphene, and gamma benzene hexachloride were exposed to adult moths in jars. Treatments were replicated three times. Introductions were made twice, one and one-half months apart. The only infestation in any treated lot was one tunnel in a tuber in one of the one-half per cent toxaphene impregnated bags after the first introduction. All three checks became infested after each introduction, the first time with 13 tunnels, and the second with more than 100.

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Erythroneura dolosa and *E. plena* on Sweet Cherry in Washington[1]

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The leafhopper *Erythroneura dolosa* B. & G. and a closely related species, *E. plena* Beamer, have been on the increase in eastern Washngton, and, in some cases, have injured sweet cherries. In 1947, while investigating possible vectors of virus diseases of cherry, the authors found these species abundant in several sweet cherry orchards in the Wenatchee and Yakima areas of central Washington, near Clarkston in southeast Washington, and in the Kettle Falls area in the northeastern part of the state. Infestations had increased by the summer of 1950 to a point that orchardists were inquiring about the insect, and control measures were necessary in a few orchards in north central Washington.

The pale yellowish-white leafhoppers are approximately 3 mm. long and are marked dorsally with orange to red lines. They oviposit in the tissue on the lower surface of the leaves. The nymphs are inactive. The adults, on the other hand, are very mobile and fly readily when disturbed.

Leafhopper populations may increase greatly by autumn. In one orchard where leafhoppers were counted on 100 leaves from the inner portions of 6 trees, an average of 16 adult *Erythroneura* were recorded for each leaf. These counts were made in early morning while the leafhoppers were inactive because of low temperatures. In another orchard, 500 insect net sweeps were made on cherry foliage, and 6194 leafhoppers were counted.

On December 2, 1948, after the leafhoppers had dropped to the ground with the leaves, 392 live adult leafhoppers were counted in leaves within 1 square foot approximately 2 feet from the tree trunk. The average number from 10 trees was 139 leafhoppers per square foot. They were found in the middle layer of leaves where moisture and fungus infection were at a minimum. The degree of winter survival is not known.

In Washington, sweet cherry appears to be the principal breeding host of *Erythroneuna dolosa* and *E. plena*, although specimens have been collected from peach, chokecherry, and many other plants. McConnell (1931) showed that *E. plena* caused a stippling of peach leaves. However, injury to peach in Washington has not been reported. *E. dolosa* would not reproduce when confined to peach seedlings under greenhouse conditions.

According to DeLong & Knull (1945), *E. dolosa* has been reported from British Columbia, Washington, and Oregon; and *E. plena* from Illinois and Kansas. Our survey indicates that *E. dolosa* is dominant in central Washington, while *E. plena* is more abundant in the northeastern part of the state.

Injury is diagnosed by a white stippling of the foliage. As an infestation becomes more severe, the white spots become more abundant until the entire leaf becomes pale green or white. They feed almost

[1] Scientific Paper No. 1009, Washington Agricultural Experiment Stations, Institute of Agricultural Science, The State College of Washington, Pullman.

Table 1.—Effect of DDT and parathion sprays for the control of the leafhopper *Erythroneura dolosa* on sweet cherry, Wenatchee, Washington, 1950.

Material	Concentration per 100 Gal.	Average Pre-Treatment Counts	Average Post-Treatment Counts			
		Sept. 8	Sept. 9	Sept. 11	Sept. 14	Sept. 26
DDT	2 lbs. 50% wettable powder	735.5	49.2	68.2	24.7	29
Parathion	.5 lb. 25% wettable powder	976.5	235.5	55	31	35.2
No treatment	—	566.2	523.7	507.5	508.5	416.7

entirely on the lower surface of the leaves. Damage is most severe on the shaded inside and lower portions of the trees. These species frequently appear along with *Typhlocyba rosae* (L.) and the injury may represent the feeding of both.

Because of the severe injury to cherries in some areas, spray applications using DDT and parathion were applied with a portable hand spray unit at 550 to 600 pounds pressure, to determine their efficacy against the leafhopper, *E. dolosa*. The trees were divided into four single tree plots for each insecticide and two untreated trees for checks. The spray was applied on the same day the pre-treatment counts were made. Pretreatment and post-treatment counts of leafhoppers are shown as average per tree.

The essential data are recorded in table 1.

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Control of the Red-Legged Grasshopper on Alfalfa with a Low Volume-Low Pressure Sprayer

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In New York, there are 31 genera and 58 species of short-horned and pigmy grasshoppers (Leonard 1928) but in most years few of the species appear in numbers large enough to warrant measures for their control. However, during the past 5 years and especially during 1947 and 1949, heavy intestations of the red-legged grasshopper, *Melanoplus femur-rubrum* DeGeer, and the two-lined grasshopper, *Melanoplus bivittatus* Say, have caused extensive damage to forage, vegetables, and fruit crops in northern New York. Preliminary experimental work on the control of grasshoppers on alfalfa and red clover with the use of a power forage duster was initiated on commercial acreages of these crops in 1947 and has been reported in an earlier paper (Gyrisco & Marshall 1950). During the past season, a heavy infestation of red-legged grasshoppers developed in northern New York centered in Oswego and Jefferson counties. Fortunately, forage insect experiments are normally conducted in those areas so that there was an excellent opportunity to determine the effectiveness of several organophosphorous and chlorinated hydrocarbon insecticides when used as sprays applied with a low volume-low pressure sprayer.

Material and Methods.—Most of the insecticides that were used were proprietary formulations of emulsifiable concentrates. A toxaphene emulsifiable concentrate, however, was prepared by dissolving technical toxaphene in refined kerosene to which a specific amount of a commercial emulsifier[3] was added. All of the insecticides were applied as emulsions at the rates of 0.2, 0.4, 0.6 and 0.8 pounds of actual toxicant per acre with a low volume-low pressure, trailer-type, weed sprayer[4] which had an 18-foot boom suspended so that the spray from the 15 fan-type nozzles coalesced just above the plants. At a pressure of 40 pounds per square inch, the sprayer delivered a gallon of spray per minute or at the truck speed of 1 mph, the sprayer delivered approximately 20 gallons of spray per acre.

The unreplicated blocks which were 60 by 80 feet in size were laid out in tandem for each material in a large uniform field of Ontario Variegated alfalfa at Minetto, New York. No buffer strips of untreated alfalfa were left between the various plots or the different insecticides, but two large untreated areas, one on each side of the treated plots, were designated arbitrarily as A and B and these areas served as checks.

Each concentration of each emulsifiable concentrate was weighed out accurately for each plot and then diluted with 2.3 gallons of water or just enough water to completely cover each plot. A by-pass valve in the sprayer permitted adequate agitation when the machine was allowed to run for a minute or two before treatment commenced. All the materials were applied in the quiet of the evening of July 25.

Grasshopper counts were made from net sweepings by taking 20 full-arm single strokes with a short (20-inch) handled 15-inch net at the various time intervals designated in the table. Each series of sweeps was taken alternately across the diagonals of the plots so that the same area was sampled only twice over a 2 or 3 week period.

Results and Discussion.—All of the insecticides, at all the concentrations used, killed more than 98 per cent of the grasshoppers in 2 days. Samples of grasshopper populations taken as late as 1 month after spray applications revealed that concentrations as low as 0.20 pounds of all the chlorinated hydrocarbon insecticides tested gave satisfactory control of the grasshoppers present. Benzene hexachloride,

[1,2] Graduate student assistants and Associate Professor, respectively, in the Department of Entomology.
[3] B-1956, Rohm & Haas Co.
[4] Myers' "Silver Cloud" Weed Sprayer.

Table 1.—Summary of the control of the red-legged grasshopper on alfalfa with seven chlorinated hydrocarbon and organophosphorus insecticides at four levels of toxicant per acre applied as emulsions with a low volume-low pressure sprayer on July 25, 1950. Minetto, New York.

Insecticide	Act. Tox. in Lbs./Acre	No. Grasshoppers Taken in 20 Sweeps			
		48 Hrs.	1 Wk.	2 Wks.	4 Wks.
Tetraethyl pyrophosphate	0.2	0	13	39	22
	0.4	0	16	38	6
	0.6	0	12	16	16
	0.8	0	10	12	36
Chlordane	0.2	1	1	3	4
	0.4	0	0	1	1
	0.6	0	0	0	3
	0.8	0	0	1	3
Aldrin	0.2	1	0	0	2
	0.4	0	0	0	0
	0.6	0	0	0	0
	0.8	0	0	0	1
Toxaphene	0.2	1	2	1	3
	0.4	1	0	1	0
	0.6	0	0	0	0
	0.8	1	0	0	1
BHC	0.2γ	0	0	0	0
	0.4γ	0	0	0	0
	0.6γ	0	0	0	0
	0.8γ	1	0	0	0
Dieldrin	0.2	0	0	0	0
	0.4	2	0	0	0
	0.6	0	0	0	0
	0.8	0	0	0	0
Heptachlor	0.2	4	0	16	11
	0.4	2	0	11	6
	0.6	0	0	5	9
	0.8	0	0	2	3
Check	A	226	327	104	26
	B	263	321	117	21

dieldrin, and aldrin, closely followed by toxaphene, at all the concentrations used were the most outstanding insecticides tested over the month period (Table 1). Chlordane and heptachlor, while giving good control of the red-legged grasshopper, were inferior to the other materials especially in their residual toxicity. Tetraethyl pyrophosphate gave excellent immediate kills of grasshoppers but did not keep the population of hoppers at as low a level over the test period as did the chlorinated hydrocarbons. However, this loss of toxicity is correlated with a rapid loss in insecticidal residue which suggests the possible use of tetraethyl pyrophosphate where grasshoppers are a problem of forage crops, especially near harvest, when such hay is to be fed dairy cattle or animals being finished for slaughter.

No phytotoxicity was experienced with any of the emulsions at any of the concentrations that were used.

The low volume-low pressure sprayer proved highly satisfactory for controlling grasshoppers under the typical hillside topography of New York. In addition, the use of a sprayer in place of a duster, which is commonly used on forage crops, makes it possible to treat during unfavorable dusting conditions and also reduces drift which may contaminate adjoining fields and pastures.

Summary.—Seven different chlorinated hydrocarbon and organophosphorous insecticides, as emulsions, were applied at 4 different concentrations per acre for the control of the red-legged grasshopper. All of the materials were applied with a low volume-low pressure sprayer at the rate of about 20 gallons per acre and a pressure of 40 pounds per square inch. All of the insecticides at all the concentrations used gave excellent control of the hoppers in 2 days. Benzene hexachloride, dieldrin, and aldrin closely followed by toxaphene were the outstanding materials tested over the month period. Tetraethyl pyrophosphate, while possessing little residual effectiveness, gave good immediate kill of grasshoppers.

The low volume-low pressure sprayer proved practical under New York conditions.

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Leafhopper Transmission of Western X-Disease[1, 2]

H. R. Wolfe.[3] E. W. Anthon,[4] G. H. Kaloostian[5] and L. S. Jones[5]

The Western X-disease, a virus disease economically important in peach, is receiving increasing attention from plant pathologists and entomologists. It has been considered to be a counterpart of the disorder designated as X-disease by Stoddard in Connecticut (1933). Western X-disease has been reported in Idaho by Blodgett (1937) in Washington by Reeves & Hutchins (1940), in Utah by Richards (1940), in Oregon by Zeller & Evans (1941), in Colorado by Bodine & Durrell (1941), and in California a related or identical disease was described by Thomas *et al.* (1940), and termed "leaf-casting yellows of peach."

The virus or viruses which produce Western X-disease are considered to be primary causative agents infecting sweet and sour cherries to produce the damaging disease being termed "Western-X-little-cherry." As with X-disease in eastern United States, native chokecherries are considered hosts, *Prunus virginiana* var. *demissa* (Nut.) being the western species; a red-leaf condition is a symptom in the chokecherry.

Stoddard stated (1938) that X-disease infection in peach orchards spreads from adjacent diseased chokecherry. Throughout the East the elimination of

[1] Scientific Paper No. 1004, Washington Agricultural Experiment Stations, Institute of Agricultural Sciences, The State College of Washington, Pullman. The federal support of the work has been from RMA funds.

[2] For helpful assistance and aid in diagnosis the authors wish to express their appreciation to E. C. Blodgett and R. C. Lindner of the Washington Agricultural Experiment Stations; S. C. Jones, J. A. Milbrath, and H. J. O'Reilly of the Oregon Agricultural Experiment Station; B. L. Richards and G. W. Cochran of the Utah Agricultural Experiment Station; L. C. Cochran, E. L. Reeves, H. C. Kirkpatrick, and B. N. Wadley of the U.S.D.A. Agriculture Research Administration, Bureau of Plant Industry, Soils and Agricultural Engineering.

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[5] U.S.D.A. Agricultural Research Administration, Bureau of Entomology and Plant Quarantine.

chokecherries for a distance of about 500 feet is regarded as effective in the control of X-disease. Opposed to this, the Western X-disease has been shown to move from diseased peach to healthy peach, and it appears to spread within the bounds of commercial orchards.

In the West the role of diseased chokecherries in spread of the Western X-disease to peach has not been proved, but spread of the disease is taking place in peach in the absence of the native chokecherries. Similarly spread of Western-X-little-cherry appears to take place within commercial cherry orchards without requiring the influence of any other stone fruit hosts, chokecherry or peach.

The first insect vector of the Western X-disease established has been the geminate leafhopper, *Colladonus geminatus* (Van D.)[6] (Wolfe *et al.* 1950). There is a short list of cicadellids whose habits are essentially similar to those of this insect, and which are able to survive for prolonged periods on stone fruit hosts; these are the subject of continuing research with the expectation that certain of them may prove to be vectors of the disease. However, surveys have shown that the geminate leafhopper is possibly the most consistently conspicuous vector suspect in the Western X-disease areas of the Northwest and Utah where most of our work has been done. Its favorite hosts are leguminous plants and grasses; however, when caged it will live and reproduce on peach, apricot, and cherry. This insect has been observed feeding on peach and cherry under natural conditions. It has also been collected from chokecherry, pin cherry, willow, and other plants which may possibly serve as virus reservoirs.

Table 1.—Transmissions of Western X-disease to peach by *Colladonus geminatus* which fed upon two separate sources of inoculum, Western-X-little-cherry affected sweet cherry and Western X-diseased peach. Wenatchee, Washington, 1949–50.

Stages of Insects	No. Tests	Days Insects on Inoculum	Transmissions	Negative Tests
Nymphs and Adults	5	1 to 7	1	4
Nymphs and Adults	20	8 to 14	10	10
Nymphs and Adults	1	15 to 21	0	1
Nymphs and Adults	1	22 to 28	0	1
Adults	1	1 to 7	1	0
Adults	3	8 to 14	0	3
Totals	31		12	19

In the first successful transmissions the leafhoppers were fed upon both infected peach and cherry before transfer to healthy peach. In the most recent experiments transmissions have been secured to peach with insects which were initially fed only on diseased peach. Test peach trees have included both potted Lovell seedlings and standard variety trees in field plots. The Western X-disease affects all common peach varieties. In experiments the disease has been produced in the field by insect inoculations as late as the latter part of August.

Insect populations have been secured through rearing upon suitable hosts in cages in the greenhouse and through collections made in the field.

In experiments involving field plot trees at The Dalles, Oregon, in 1948 (Wolfe *et al.* 1950 and in press 1951) one transmission of X-disease to peach was secured in a series of transfers of *Colladonus geminatus* to 28 test peach trees. The insects used had been fed on both Western-X-little-cherry affected sweet cherry and Western X-diseased peach before their transfer to healthy trees.

In experiments during 1949 and 1950, at Wenatchee, Washington, involving transfers of *Colladonus geminatus* to a total of 31 trees, 12 transmissions were achieved (Table 1). The number of insects used in each transfer varied from 1 to 25. Untreated control trees kept in numbers approximating the numbers of test trees all remained healthy. These tests likewise involved the exposure of each lot of insects to two sources of inoculum, namely Western-X-little-cherry in sweet cherry and Western X-disease in peach. Thus, while the capabilities of the leafhopper in transmitting the disease to peach were determined, the source of the virus, peach or cherry or both, was not known.

Later experiments, which this report will discuss, have demonstrated that the disease can be transmitted from diseased peach to healthy peach.

The peach to peach transmission of Western X-disease was determined in two series of tests completed at Wenatchee, Washington, in 1949 and 1950, and in similar experiments at Logan, Utah, in 1950. Table 2 summarizes the Washington experiments, showing five positive cases of transmission from 46 trials. Untreated control trees remained normal. The number of insects used in each transfer varied from 1 to 25.

From a considerable number of experiments with this leafhopper in Utah, transfers to two trees resulted in successful transmissions from peach to peach. The circumstances of the work, which was in the greenhouse, gave an indication that the virus underwent a latent period of at least 36 days in the insects. The details of the two tests show, (1) 20 adults and nymphs fed for 7 days on Western X-diseased peach. They were transferred to a healthy peach upon which they fed for 36 days. This tree did not become infected. Fifteen surviving leafhoppers were transferred to a second healthy peach where they fed for 30 days. This second tree showed severe Western X symptoms in about a month. (2) Forty adults fed for 9 days on Western X-diseased peach. They were transferred to a healthy peach upon which they fed for 33 days. This tree did not become infected. Fifteen surviving leafhoppers were transferred to a second healthy peach where they fed for 23 days. This second tree showed severe Western X symptoms.

Table 2.—Transmissions of Western X-disease to peach by *Colladonus geminatus* which fed on only diseased peach as inoculum. Wenatchee, Washington, 1950.

Stages of Insects	No. Tests	Days Insects on Inoculum	Transmissions	Negative Tests
Adults	29	1 to 7	2	27
Adults	1	8 to 14	0	1
Adults	12	15 to 21	3	9
Adults	4	22 to 25	0	4
Totals	46		5	41

At Wenatchee, Washington, in 1950 a serial transfer study was made with 17 groups of insects, involving 1 to 5 insects per group, following feeding periods of 7, 12, and 30 days on Western X peach inoculum. Four to 11 test trees were involved for

[6] The leafhoppers used in these experiments were identified by P. W. Oman, United States Bureau of Entomology and Plant Quarantine, Division of Insect Identification.

Table 3.—Transmissions of Western X-disease to peach by *Colladonus geminatus* which fed upon diseased peach as inoculum, with subsequent transfer serially to healthy peach trees. Wenatchee, Washington, 1950.

Insect Group Number	Days Insects Were on Inoculum	Numbers Indicate Days Insects on Test Trees. Transmission Indicated by (+). No Transmission Indicated by (−)										
		Tree No.										
		1	2	3	4	5	6	7	8	9	10	11
1[1]	7	7	7	14	14	14	7	7[4]				
		−	−	−	−	+	+	−				
2	7	7	7	14	14							
		−	−	+	+							
3	7	7	7	14	14	14	7	7	7	7	7	
		−	−	−	+	+	+	−	−	−	−	
4	7	7	7									
		−	−									
5	7	7	7	14	14	14	7	7				
		−	−	−	−	−	−	−				
6	7	7	7	14	14	14	7	7				
		−	−	−	−	−	−	−				
7	7	7	7	14	14	14	7	7				
		−	−	−	−	−	−	−				
8	7	7	7	14								
		−	−	−								
9	7	7	7	14	14	14	7	7	7	7	7	7
		−	−	−	−	−	−	−	−	−	−	−
10	7	7	7	14								
		−	−	−								
11[2]	12	9	12	9	12	9						
		−	−	+	+	+						
12[3]	30	9	9	12								
		−	+	+								
13	30	9	9	12	8	7						
		−	−	−	+	−						
14	30	7	9	7	8	7	7					
		+	−	−	−	−	−					
15	30	20	20	20								
		−	−	−								
16	30	7	7	14	7	14	7	14				
		−	−	−	−	+	+	+				
17	30	7	7	14	7							
		−	−	+	+							

[1] In groups 1 to 10, there were 1 to 5 adult leafhoppers.
[2] In group 11, there were 1 or 2 adult leafhoppers.
[3] In groups 12 to 17, there were 1 to 5 adult leafhoppers.
[4] The discontinuance of each series of transfers was due to death of the last survivor in each group of insects.

each group of insects, depending upon survival of the insects in the groups. Equal numbers of control trees remained healthy. A total of 94 trees were test-inoculated and 19 cases of disease were produced (Table 3). An examination of table 3 reveals that no transmissions occurred sooner than 35 days after the earliest feeding on inoculum. Again this indicates the existence of a relatively long latent period for the virus complex in the insects. Also in this experiment some insects were infective for at least 58 days after exposure to inoculum. The leafhopper was capable of transmitting to three trees in succession when moved at intervals of from 1 to 2 weeks. Transmissions have been secured with single insects. While transmission has generally occurred only after a latent period of the virus in the leafhoppers of 30 or more days, there is in our records one instance of transmission with apparently no more than 22 days from the time of exposure of insects to inoculum until they were removed from the test tree.

Summary.—The Western X-disease of peaches has been transmitted by the geminate leafhopper, *Colladonus geminatus* (Van D.) in experimental work in Washington, Oregon, and Utah.

The first evidence of insect transmission to peach was obtained through transfers of the leafhoppers which had fed upon two potential sources of inoculum, Western-X-little-cherry, affected sweet cherry and Western X-diseased peach. Later work showed that the insects are able to transmit the disease from peach to peach. A total of 39 transmissions of Western X-disease with *Colladonus geminatus* have been secured.

The latent periods thus far demonstrated for the virus in the insect have generally ranged more than 30 days, with one instance of 22 days. Some leafhoppers have remained infective for at least 58 days. Transmissions have been secured with single insects. The leafhopper was capable of carrying the disease to three trees in succession when moved at weekly intervals.

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Control of the Sand Wireworm with Chlorinated Insecticides[1]

J. G. WATTS[2] and W. C. NETTLES[3]

For many years farmers over much of the coastal plains area of South Carolina have been confronted with the perplexity of growing crops in soils infested with sand wireworms, *Horistonotus uhlerii* Horn. Until recently there were only a few partially effective tools with which to fight this problem. A combination of crop rotation, land resting, increasing soil humus and fertility, resistant crops and planting dates provided a reasonable solution for the few who owned sufficient land for the employment of these practices. On the average farm a balanced economy could not be maintained under the cropping system imposed by such practices.

In 1948 experiments and field demonstrations were set up to determine the effect of several of the chlorinated hydrocarbons upon the sand wireworm. Chlordane, benzene hexachloride, Toxaphene and DDT were each tested at four different rates in a field with a history of heavy wireworm infection, however only a moderate infestation developed during this season. The insecticides were mixed with fertilizer and applied to the soil immediately before planting. Data are given in table 1.

Table 1.—Yield response of corn to insecticide-fertilizer mixtures applied for the control of the sand wireworm, 1948.

YIELD RATING	TOXICANT	TOXICANT PER ACRE	BUSHELS PER ACRE
1	Chlordane	0.5	26.5
2	Chlordane	4.0	24.8
3	DDT	4.0	24.4
4	Chlordane	2.0	22.3
5	Toxaphene	1.0	22.0
6	Chlordane	1.0	21.5
7	γBHC	0.125	19.9
8	Toxaphene	0.5	19.9
9	γBHC	0.5	19.3
10	Toxaphene	4.0	19.2
11	Toxaphene	2.0	18.8
12	γBHC	0.25	18.7
13	DDT	0.5	18.4
14	γBHC	1.0	16.7
15	DDT	2.0	16.0
16	DDT	1.0	15.7
17	Check, untreated	—	15.3

In no case did the corn yield vary directly with an increase or decrease of a particular toxicant, probably because of a lack of uniformity in infestation. Infestations of this species are normally quite spotted in any given field and it is extremely difficult to determine just where an infestation will develop. There were four replicates in this experiment but it is evident that a substantially larger number is needed to compensate for the lack of uniformity in population which may be normally anticipated. In this test, however, the several rates of chlordane were more consistent in increasing corn yield than

Table 2.—Results of wireworm control demonstrations on corn in Bamberg County, 1948.[1] Toxicants were mixed and applied with the fertilizer.

TREATMENT	POUNDS OF TOXICANT PER ACRE	PLOT SIZE IN ACRES	WIREWORM DAMAGE	YIELD, BUSHELS PER ACRE
Chlordane	2.0	1.0	none	30.0
γBHC	0.5	1.0	none	25.0
γBHC	0.25	1.0	none	24.4
Check	—	1.0	severe	5.8
Chlordane	1.87	2.5	none	25.0
γBHC	0.47	2.5	none	30.7
Check	—	2.5	severe	14.0
Chlordane	0.63			
γBHC	0.19			
DDT	0.63	2.0	none	12.0
Check	—	1.0	severe	5.0
Chlordane	0.50			
γBHC	0.15			
DDT	0.50	1.0	none	20.0
Check	—	0.25	severe	2.0
Chlordane	0.88			
γBHC	0.21			
DDT	0.88	2.0	none	25.0
Check	—	1.0	spotted	15.0

[1] These demonstrations were conducted by County Agent, R. C. Hubbard Jr.

[1] South Carolina Agricultural Experiment Station Technical Contribution No. 177.

[2] Entomologist, Edisto Branch, S. C. Agricultural Experiment Station, Blacksville, S. C.

[3] Leader, Entomology and Plant Disease Work, S. C. Extension Service, Clemson, S. C.

Table 3.—Results of wireworm control demonstrated on corn in Barnwell County, 1948.[1] Toxicants were mixed and applied with the fertilizer.

Treatment	Pounds of Toxicant per Acre	Plot Size in Acres	Wireworm Damage	Yield, Bushels per Acre
Chlordane	1.0	0.5	none	25.0
γBHC	0.15	0.5	none	24.0
γBHC	0.30	0.5	none	26.0
Check	—	0.5	severe	5.0

[1] These demonstrations conducted by County Agent, D.A. Shelly.

any of the other toxicants. There was a rather phenomenal difference in plant growth between the chlordane treated and the untreated plots.

There was a great deal of public interest in these tests and many farmers, fertilizer manufacturers, and agricultural workers visited them on various occasions. The farmers, in particular, were so impressed with the results which they observed that they were ready to adopt this procedure for wireworm control without further experimentation. A definite recommendation at this time on the use of an insecticide-fertilizer mixture for wireworm control was, of course, considered premature. Despite this, however, in 1949 an estimated 50 per cent of all corn planted on land with a wireworm history was treated with a chlordane-fertilizer mixture at the rate of one pound of toxicant per acre. In 1950 an estimated 90 per cent of all corn planted on land with a wireworm history was so treated. The employment of this simple and relatively cheap means of controlling sand wireworms has become so general until there is some difficulty in finding untreated infested fields for experimentation. Field plot work was greatly expanded in 1949 and 1950 but in neither year did a sufficient population develop on the untreated checks to show a difference due to treatment.

DDT Recovered on Corn Plants from Different Treatments against Corn Earworm[1]

J. M. GINSBURG and R. S. FILMER, *New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick*

The use of DDT to control corn earworm has become a standard practice in New Jersey. Although the official recommendation calls for dusting with 3 to 5 per cent DDT, some growers have sprayed DDT-oil emulsion onto the silks,[2] and in a few instances injections of oil-DDT solution into the husk tips were also used. Since it is the general practice among farmers to feed the corn stalks and husks to livestock, it became of interest to determine the amount of DDT remaining on the plant at harvest.

For this purpose several plots of seed-corn (variety—♀ and ♂ parent plants of N. J. No. 7) raised on a commercial farm were dusted, sprayed and injected with DDT and analyzed at harvest for DDT residues. Three applications of 5 per cent DDT dust by ground power duster at 40 lbs. per acre were made on August 8, 16 and 21. The oil emulsion spray contained 0.75 per cent actual DDT and was applied at the rate of 2 lbs. DDT per acre with a wheel barrel type power sprayer on August 11. For the injection procedure white mineral oil containing 1 per cent DDT was applied on August 26 with a force oil dispenser, delivering approximately 0.75 ml. into each husk tip, amounting to 7.5 mg. DDT per ear.

Samples of entire corn plants were collected at harvest, October 19, and processed for chemical analyses. The rainfall from treatments to harvest averaged 6.15 inches. Separate DDT analyses were made on the following plant parts: (1) leaves and stalks combined, (2) husks, (3) eartips and (4) shelled kernels.

PROCESSING OF SAMPLES.—The husk and silk were removed from the ear. The ear tips were then cut off at the area where the round seeds end and the flat seeds begin, about 2 to 2.5 inches from the top. The shelled corn grain as well as the ear tips were disintegrated in a Waring blendor and then extracted with benzene. The husks, leaves and stalks were cut into small pieces and also extracted with benzene. The extraction was carried out for about 40 minutes on a mechanical shaker. The filtered extracts were treated with anhydrous Na_2SO_4 to remove traces of water, decolorized and aliquots analyzed for DDT. The leaves and stalks were analyzed by the nitration colorimetric method; and the eartips and kernels by the total organic-chlorine procedure.

Table 1.—DDT residues on corn plants variously treated.

Treatments	DDT per Acre Lbs.	Part of Corn Plant	DDT P.P.M. Green Wt.
5 per cent DDT powder dusted three times	6	Leaves & Stalks	6.50
		Husks	23.63
		Kernels	0.0
		Ear tips	0.0
DDT-oil emulsion hand sprayed once	2	Leaves & Stalks	50.92
		Husks	21.32
		Kernels	0.0
		Ear tips	0.0
DDT-oil tip injections	0.2[1]	Husks	26.17
		Kernels	0.0
		Ear tips	52.85

[1] Based on 12,000 plants per acre and one ear per plant.

The results, summarized in table 1, brought out the following information. No DDT was present in the shelled kernels from any of the three treatments. Large amounts (about 52 ppm.) of DDT were recovered from eartips injected with DDT-oil, but none was found in eartips from dusted or oil-emulsion sprayed plants. Relatively large amounts of DDT were present on the husks from each of the three treatments. Leaves and stalks from the DDT-oil emulsion sprayed plot contained several times as much DDT (50.92 ppm) as did the leaves and stalks from the dusted field (6-5 ppm).

CONCLUSIONS.—The results indicate that corn leaves, stalks and husks sprayed with DDT-oil emulsion retain excessive amounts of DDT at harvest. Oil-DDT injections leave large quantities of DDT on eartips and husks. DDT-residues from dust applications are larger on husks than on leaves and stalks.

[1] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, The State University of New Jersey, Department of Entomology.

[2] Following the procedure recommended in U.S.D.A. Leaflet No. 284.

A New Method for Rearing Drosophila and a Technique for Testing Insecticides with this Insect

B. R. BARTLETT,[1] *University of California Citrus Experiment Station, Riverside*

Investigation of *Drosophila melanogaster* Meig. as a test insect for assessing the toxicity of insecticides has claimed the attention of many entomologists. Most notable are the contributions of a group of Canadians (Stultz 1939; Morrison 1943, 1946; McLeod 1944) who have studied in detail the role of environmental factors responsible for insecticidal test variance with this insect.

Where determinations of small differences in toxicity are demanded in an insecticidal test, *Drosophila* has distinct limitations, due primarily to its extreme sensitivity to moisture content of food and to humidity conditions both prior to and during test periods. That much of the variability in results of insecticidal tests with this insect can be eliminated by careful attention to these details has been demonstrated, but the care that must be expended is rarely justifiable if more adaptive test insects can be obtained. However, when specialized purposes warrant extensive care or when only rough evaluation of candidate insecticides is necessary, as is often the case in a screening program, the use of *Drosophila* as a test species has considerable merit. A brief description of a method of rearing *Drosophila* and of a screening technique used successfully at the Citrus Experiment Station of the University of California therefore seems worth while.

For insecticidal test purposes, the *Canton-S* strain of *Drosophila melanogaster* has been shown to have a higher degree of native vigor and greater adaptation to environmental conditions than a number of the more highly selected strains. This wild type is readily obtainable at most institutions where genetic studies are conducted.

The use of canned custard pumpkin as a laboratory food medium was suggested by the natural feeding of *Drosophila* on ripening banana squash in the field. This new food material has made possible the development of a rearing method which combines simplicity of operation with the advantage of a high food-moisture content. Canned custard pumpkin is poured into a 1-gallon glass jar to a depth of 2 inches, and several paper towels are pushed down around the inner sides of the jar to serve as pupation strips. The jar is infested with 150 to 200 adult flies, and the mouth is covered with a paper towel which is held in place with rubber bands. Adult flies die within a few days on this medium, but enough eggs are laid in each jar to produce 3,000 to 4,000 well-developed test flies. The freshly emerged flies are liberated daily from the jars into a randomization cage, where large cotton pads saturated with 5 per cent honey solution supply food as well as high humidity during the 2-day confinement before use in insecticidal tests. No second generations are reared on the medium, but a simple rotation of fresh culture jars and randomization cages maintains fresh test stock at all times. Sufficient yeast spores are carried by the infesting stock to the new medium so that yeast inoculation is unnecessary, and unless mold spores become very abundant from old medium jars the natural antibiotics produced by the developing larvae prevent mold growth. Adult flies and culture jars are held at 25° C. Canned custard pumpkin is economical, easily available, and sterile when removed from cans. It appears to be an ideal medium for development of larval stages.

The technique of contact insecticide evaluation which has given the best results at Riverside, using *Drosophila*, is a modification of the method described by Morrison (1946). A filter paper 9 cm. in diameter is impregnated with 1 ml. of a standard acetone solution of the insecticide to be tested, then dried and placed in the bottom of a petri dish 9 cm. in diameter. A small dish of cotton saturated with 5 per cent honey solution supplied food and moisture. Fifty to 100 adult flies are chilled to inactivity by 2 minutes' exposure in the freezing compartment of an electric refrigerator before transfer to the petri-dish test unit. Periodic counts of accumulated mortalities are used to determine the period of 50 per cent kill, expressed on an exposure-time basis. Flies which are incapable of standing are counted as dead. Five test units of 50 to 100 flies each are used to determine time values required for 50 per cent kill with each insecticidal formulation. With most materials and dosages a coefficient of variation of less than 10 per cent has been obtained with this method of culture and test. Comparisons using this technique of testing have consistently shown statistical significance not obtainable with other methods.

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[1] Assistant Entomologist in the Experiment Station.

Tests with Two Insecticidal Aerosols for Use on Aircraft

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Since 1942 insecticidal aerosols have been employed for the control of insects of public-health importance on aircraft entering the United States. Such use was first suggested by Sullivan *et al.* (1942). The first formulation used by the U. S. Public Health Service at the port of Miami (Dunnahoo 1943) contained 2 per cent of pyrethrins made from a 20 per cent pyrethrum extract. During World War II the Air Transport Command used aerosols containing pyrethrum and sesame oil on its routes throughout the world.

Early in 1946, after many formulas had been tested at Beltsville, Maryland, the Bureau of Entomology and Plant Quarantine recommended a formula designated as G-382 to the Public Health Service for approval for use on aircraft. This for-

Table 1.—Results of tests in a Peet-Grady chamber with two Freon aerosols approved by the U. S. Public Health Service for use on aircraft.

Dosage, Grams per 1000 Cu. Ft.	Number of Tests with Each Formula[1]	Formula G-382				Formula G-651			
		Per Cent Knock-Down in			Per Cent Kill in 1 Day	Per Cent Knock-Down in			Per Cent Kill in 1 Day
		5 Min.	10 Min.	15 Min.		5 Min.	10 Min.	15 Min.	
Musca domestica									
0.37	5	9	26	35	68	11	30	34	57
1.16	4	32	49	59	80	40	54	57	67
5	9, 4	76	88	92	98	75	85	89	96
Anopheles quadrimaculatus									
5	4	—	—	99	100	—	—	99	100
Aëdes aegypti									
5	4, 3	—	—	100	100	—	—	100	100

[1] Where 2 figures are given, the first is for G-382 and the second for G-651.

mula was approved in 1948, and its use in Public Health Service control procedures has been discussed by Hughes (1949).

Some users objected to the cyclohexanone employed as solvent in the G-382 formula, and a replacement formula was desired. A new formula (G-651) has therefore been developed which contains alkylated naphthalenes in place of cyclohexanone. The composition, filling ratio, and particle size[1] of the two formulas are shown below.

	G-382	*G-651*
Composition (per cent):		
Pyrethrum extract (20%)	5	6
DDT	3	2
Cyclohexanone	5	2
Methylated naphthalenes[2]	—	8
Lubricating oil (SAE 30)	2	—
Dichlorodifluoromethane	85	84
Nonvolatile-volatile filling ratio	15:85	16:84
Particle size (diameter in microns)		
Mean mass	14	14
Largest	45	40

Tests in a Peet-Grady chamber carried out by the authors in February 1949, the results of which are given in table 1, show that G-651 was similar to G-382 in performance against house flies, *Musca domestica* L. At 5 grams per 1000 cubic feet, which is the dosage required by the Public Health Service for use on aircraft in the presence of people, both formulas gave high performance against the house fly, the common malaria mosquito, *Anopheles quadrimaculatus* Say, and the yellow-fever mosquito, *Aëdes aegypti* (L.).

On the basis of these data, G-651 was recommended as a possible substitute for G-382, and on March 28, 1949, this formula was approved by the U. S. Public Health Service. Since that time this formula has come into use on aircraft, although G-382 is still being used by a number of commercial airlines. In a few cases formula G-651 caused nozzle stoppage, but this trouble was traced to a high wax content of the pyrethrum extract. It is important to use a pyrethrum extract containing not more than 1.5 per cent of Freon-insoluble material. For the control of agricultural insects, the Bureau of Entomology and Plant Quarantine uses the G-651 formula at a dosage of 7.5 grams per 1000 cubic feet on occupied aircraft headed for the mainland from the port of Honolulu, Hawaii, and at the 5-gram dosage at San Juan, Puerto Rico. At Honolulu this formula is also used on unoccupied planes at a dosage of 30 grams per 1000 cubic feet.

[1] The particle-size data were furnished by A. H. Yeomans of this Bureau.

[2] Either *Soracide* 544G or *Velsicol AR-60*.

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Status of the Rhodes Grass Scale Parasite in Texas

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An historical sketch of the occurrence of the Rhodes grass scale, *Antonina graminis* (Maskell), in Texas, the introduction of the parasite *Anagyrus antoninae* Timb. and some basic information concerning the life history and methods used in rearing the parasites has been reported by Riherd (1950).

The propagation and release of the parasite has been continued since the spring of 1949 when the original shipment of parasitized Rhodes grass scale was recived from the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, in Hawaii.

Prolonged periods of unusually dry and cold weather have occurred since attempts were started to establish the parasite in this area. As a consequence, a very small amount of host grasses for Rhodes grass scale are in a growing condition on the range of the King Ranch, Kingsville, Texas where the first releases of the parasite were made. At various times, parasites have also been released in irrigated areas, around an artificial lake, along irrigation canals and various other locations. The host scale in the latter instances was on Johnson grass, *Sorghum halepense;* Paragrass, *Panicum purpurascens;* St Augustine, *Stenotaphrum secundatum;* and Bermuda grass, *Cynodon dactylon.*

Apparently the parasite is not established on the ranges of the King Ranch where the host plants of the scale have suffered severely from the lack of moisture. In every case where the parasite has been released and the grass supporting the scale has remained in a growing condition, the parasite has survived and produced one or more generations. In some instances at the points of release the grass died from the lack of moisture, was burned off or was destroyed by some other means thus eliminating the parasites. At one point, a flat of parasitized scale on Johnson grass stems was placed on a canal bank in August, 1949. The Rhodes grass scale was present on St. Augustine grass growing on the banks of the canal and on Johnson grass in a near by citrus grove. *Anagyrus antoninae* emerged from scale specimens collected in this area in January, 1951. Rhodes grass scale collected on the one hundred acre Experiment Station grounds will almost invariably produce *Anagyrus antoninae*. These parasites are the progeny of a limited number of released parasites and individuals escaping from the insectary where the parasites are being reared.

The number of parasites emerging from material collected at locations where the parasite was known to be present before the recent cold weather, indicates that low temperatures have not reduced the population. According to the report of the U. S. Weather Bureau Office, Brownsville, Texas, the low temperatures during the period January 29 through February 3, 1951 compare with the most severe conditions on record for duration of low temperatures in this area. There were six days with below freezing temperatures. *Anagyrus antoninae* is known to occur in Japan where no doubt the temperatures are considerably below the temperatures occurring in this area. It is reasonable to expect that low temperatures will not be a limiting factor in the ecology of the parasite in this area.

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Influence of the Presence or Absence of the European Red Mite on Two-Spotted Spider Mite Abundance[1]

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Both the European red mite, *Paratetranychus pilosus* (C. & F.) and the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, are active in western New York apple orchards. In trees that receive no acaricide the European red mite reaches peak abundance by about mid July, whereas, the two-spotted spider mite does not build up in numbers until approximately a month later. This behavior pattern for the 1949 and 1950 seasons has been recorded in earlier papers (Chapman & Lienk 1950 and Lienk & Chapman 1951).

A question has been raised as to whether the late activity of the two-spotted spider mite is a result of some favorable complex of conditions or is the result of competition from the European red mite. An opportunity to study this question was presented in 1950. In certain mite control blocks the European red mite was virtually eliminated for the season by the use of treatments applied before blossom against the newly hatched first brood. Experience has shown that such sprays have little or no effect on the two-spotted spider mite. Population records were taken throughout the season in these and in untreated plots, and the data obtained are plotted in figure 1. These records suggest that competition of the European red mite may be an important factor in the suppression and late build up of the two-spotted spider mite. However, even in the absence of the European red mite, the two-spotted spider mite built up at a relatively slow rate and did not attain peak activity until mid August.

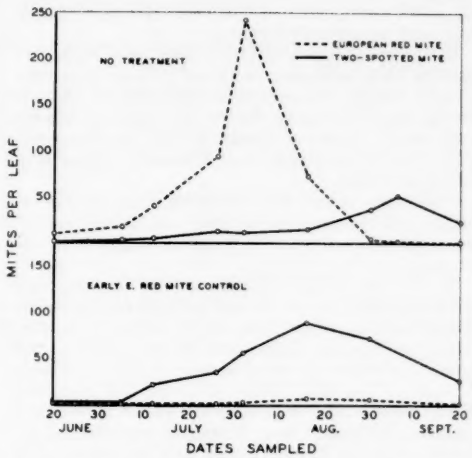

FIG. 1.—Seasonal population records of European red mite and two-spotted spider mites in untreated apple trees and in those where European red mite was controlled by pre-blossom sprays. 1950.

The implication of these preliminary findings on control practices are perhaps evident. It raises the question as to the value of using early controls for the European red mite since summer applications of acaricides are indicated whether or not early European red mite sprays are used.

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A Sweet Clover Root Borer in Texas

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During the past year, reports indicated that infestations of root borers were causing injury to Madrid sweet clover in North Texas. In some cases, the clover was completely destroyed. This insect has been identified by workers in the National Museum as *Walshia amorphella* Cl. References concerning

[1] Journal paper No. 855, New York State Agricultural Experiment Station, Geneva, New York. March 9, 1951.

the insect are few since it has been known to attack only wild leguminous plants.

Riley (1870) redescribed the insect and indicated that the little gallmaker produced galls on the stems of false indigo. He also indicated that the insect should be placed among the harmless insects. Apparently this is a case of change in food habits of the insect from a wild host to a new and perhaps preferred host plant.

The larvae tunnel into the roots from the crown (figure 1) and severe infestations completely destroy the plant. In severe cases large acreages were destroyed.

A. H. Alex of the Department of Entomology made a survey in the late fall of 1950 to determine the distribution of the pest. Heavy infestations were found in Denton, Collin and Dallas counties and lighter infestations were found in Delta, Hunt, Navarro, Ellis, Hill, McLennan and Bell counties. Madrid sweet clover, Evergreen sweet clover and common *Melilotus alba* (biennial) were found infested with the borer. Alfalfa and lespedeza were not found infested.

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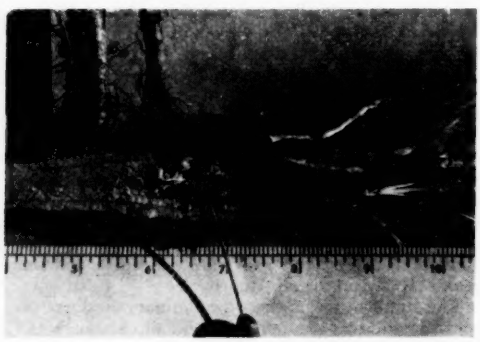

FIG. 1.—Evergreen sweet clover plant, Denton Substation, showing injury caused by the clover root borer.

Toxicity of Some Insecticides to *Nomia melanderi* and *Apis mellifera*[1]

HERMAN F. MENKE,[2] *The State College of Washington*

Nomia melanderi Ckll. (alkali bee) is the most important insect pollinator of alfalfa in certain areas of Washington. The 1950 U. S. Department of Agriculture Crop Report showed 12,000 acres of alfalfa seed harvested in Washington with an average yield of 9 bushels (540 pounds) per acre. This average yield per acre was the nation's highest. The great numbers of *Nomia melanderi* unquestionably were among the main contributing factors. Washington yields of 1700 pounds of clean seed per acre have occasionally been reported the last few years. During the 1950 season, one 10-acre field yielded 2000 pounds of uncleaned seed per acre. Destruction of these bees by indiscriminate use of insecticides would seriously reduce these yields. Experiments by Bohart & Lieberman (1949) indicated concentrations of DDT used for the control of lygus was toxic to these bees.

Last year in the lower Yakima Valley, approximately 2000 colonies of honeybees were poisoned by parathion and tetraethyl pyrophosphate used for mite control in alfalfa seed fields. Principal damage came from reduction in the field forces. In Washington, 10 per cent DDT dust applied to alfalfa seed fields in the pre-bloom stage at 20 pounds per acre has given excellent lygus bug control for the entire season. This treatment seldom causes bee poisoning. Sometimes grasshoppers move into the seed fields about midseason. Five per cent toxaphene dust at 40 pounds per acre is recommended for their control. A dust mixture of 5 per cent DDT (for lygus) and 5 per cent chlordane (for grasshoppers) caused some poisoning to alkali bees last year.

Most bee poisoning has occurred when mite controls are necessary. Even though 1 per cent tetraethyl pyrophosphate dust, 30 pounds per acre, was recommended for mite control, commercial applicators used parathion dusts principally. Application of 2 per cent parathion dust, 30 pounds per acre, was not uncommon. At the end of the season a few treatments were made with 3 per cent parathion dust, 25 to 30 pounds per acre.

MATERIALS AND METHODS.—Klostermeyer (1951) experimented with 2 per cent *TM-1*, 4 per cent *TM-1*, 2 per cent *TM-2*, and sulfur. He found 4 per cent *TM-1* gave best control for mites in alfalfa seed fields. Since bee poisoning is an important problem in a mite control program, experiments were conducted to determine the toxicity of 4 per cent *TM-1*, 2 per cent *TM-2*, and 2 per cent parathion. No tests were conducted using sulfur, since this chemical has long been known to be non-hazardous to bees. One test was made when 1 per cent tetraethyl pyrophosphate was applied to a seed field. Some experiments were also conducted when 5 per cent DDT and 5 per cent chlordane were applied to blossoming alfalfa. Bees were exposed to test materials by placing them in new, 3-pound size, package bee cages.

COMMERCIAL FIELD APPLICATION TESTS.—Two tests were made by collecting alkali bees with a sweeping net at their nesting site and putting them in two cages. One cage was kept in the cab of a truck which had the windows and doors closed. The other was placed with one screened side up, the other on the ground, in the alfalfa seed field just before treatment was made by helicopter. In the first test, the application of 5 per cent DDT and 5 per cent chlordane dust was made at 5:55 A.M. The exposed

Table 1.—Per cent of mortality in commercial field application tests using *Nomia melanderi* Ckll. Wapato, Washington, August 1950.

TREATMENT	TIME AFTER TREATMENT	CHECK	DUSTED CAGES
#1—5% chlordane, 5% DDT dust, 30 lbs. per acre	0 hours	90 bees	131 bees
	3.5 hours	5%	19%
	6 hours	27%	83%
	7 hours	35%	100%
#2—1% tetraethyl pyrophosphate dust, 30 lbs. per acre	0 hours	62 bees	173 bees
	2 hours	11%	54%
	3.5 hours	16%	95%

[1] Scientific Paper No. 1005, Washington Agricultural Experiment Stations, Institute of Agricultural Sciences, The State College of Washington, Pullman.

[2] Junior Entomologist (Agriculturist).

Table 2.—Per cent of mortality in hand dusting tests using *Nomia melanderi* and *Apis mellifera* Wapato, Washington, August, 1950.

SPECIES	TIME AFTER TREATMENT	CHECK	2% TM-2 DUST	4% TM-1 DUST	2% PARATHION DUST
Nomia	0 hours	14 bees	14 bees	14 bees	
	3 hours	0%	100%	57%	
Nomia	0 hours	30 bees	55 bees	68 bees	
	½ hour	0%	89%	1%	
	4 hours	6%	100%	7%	
	14 hours	13%	—	20%	
Nomia[1]	0 hours	34 bees	44 bees	46 bees	48 bees
	2½ hours	0%	90%	0%	4%
	7 hours	0%	100%	0%	29%
	15 hours	0%	—	8%	37%
Apis	0 hours	160 bees	55 bees	164 bees	52 bees
	10 minutes	0%	0%	0%	0%
	50 minutes	0%	98%	.6%	100%
	3½ hours	24%	100%	21%	—

[1] The parathion cages were treated 6 hours before the bees were added; all other treated cages were dusted 48 hours previous to introducing the bees.

cage was removed from the field at 6:15 A.M. (temperature 68° F.) and placed in the shade with the check cage (Table 1).

The second commercial field application tests was conducted the same as the first, except the cage was removed from the field immediately after the helicopter dusted it using 1 per cent tetraethyl pyrophosphate. The field was dusted at 8:32 A.M. when the temperature was 80° F. (Table 1).

HAND DUSTING TESTS.—All the hand dusting tests were conducted by thoroughly dusting the inside area of package bee cages with new hand flit guns. A different gun was used for each insecticide. The recently netted bees collected as above, were added immediately, except where otherwise noted. The honeybees were taken from the third story of a strong colony a few minutes before placing them in the experimental cages.

These experiments were conducted in a shed which furnished shade and wind protection as there are no laboratory facilities in this region. The weather was generally fair, with maximum daytime temperatures around 85° F. and minimum night temperatures about 65° F. Individual cages were spaced 3 feet apart to eliminate contamination. One per cent parathion dust, 2 per cent parathion dust, 2 per cent *TM-2* dust, and 4 per cent *TM-1* dust were used.

Results are given in table 2. *Nomia* tests 2 and 3, and *Apis* test 1 were run in duplicate. The figures given are the combined totals.

RESULTS.—Only one test was made using 1 per cent parathion dust. The cage was hand dusted July 31, 8:15 P.M. and the *Nomia* bees placed in it August 1, 7:40 P.M. Twelve hours later, 72 per cent of the 25 bees were dead in the treated cage and 20 per cent of the 24 bees in check cage.

SUMMARY.—Results of the 1950 bee poisoning tests were:

A. The following materials were highly toxic to alkali bees under commercial field application.

(1) Mixture of 5 per cent DDT and 5 per cent chlordane dust—30 pounds to the acre.

(2) One per cent tetraethyl pyrophosphate dust—30 pounds to the acre.

B. When bees were placed in hand dusted cages it was found—

(1) One per cent and 2 per cent parathion dust was moderately toxic to alkali bees.

(2) Two per cent *TM-2* dust was very toxic to alkali bees and honeybees even 48 hours after application.

(3) Two per cent parathion dust was very toxic to honeybees.

C. Since 4 per cent *TM-1* dust, 50 pounds per acre, controls mites effectively in alfalfa seed fields and is apparently only slightly toxic to alkali bees and honeybees, it may have an important place in legume seed production where mite control and bee poisoning are conflicting problems.

LITERATURE CITED

Bohart, George E., and F. V. Lieberman. 1949. Effect of an experimental field application of DDT dust on *Nomia melanderi*. JOUR. ECON. ENT. **42**(3): 519–22.

Klostermeyer, E. C. 1951. Control of mites on alfalfa and clover seed crops. JOUR. ECON. ENT. **44**(1):

CHRISTENSON SUCCEEDS CARTER

Walter Carter who organized and directed the BEPQ investigations on the control of the oriental fruitfly in the Hawaiian Islands has resigned to return as entomologist to the Pineapple Research Institute in Honolulu. He has been succeeded by Leroy D. Christensen a graduate of Utah State who entered BEPQ in 1926.

EDITORIAL

Registration and Labeling of Pesticides

The development of new agricultural chemicals has been particularly active during the past decade. New chemicals and new uses for chemicals are continually being developed. Hundreds of materials have shown promise in laboratory tests and await further evaluation in field trials and, behind this impending flood, thousands more are reported to be awaiting screening in laboratories to select the most promising for field trials and marketing. The number of economic poisons registered for sale in California, for example, has doubled every ten years and now approximately ten thousand products are registered. Not only has the number of pest control materials greatly increased, but some of them are extremely poisonous to human beings and their improper use may present a serious hazard to public health and safety.

The first economic poisons law was adopted by the State of New York in 1898 to regulate the sale of paris green, the most important insecticide at that time. Similar laws were adopted the following year by Oregon and Texas, and in 1901 by California, Louisiana, and Washington. In 1910 the Federal Insecticide Act was passed. It was not until 1947 that the Federal Insecticide, Fungicide and Rodenticide Act was passed to provide coverage of all economic poisons. The term "economic poison" means any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any insects, rodents, fungi, weeds, and other forms of plant or animal life or viruses, except viruses on or in living man or other animals, which have been declared to be a pest. To avoid the implication that all economic poisons are highly toxic to human beings, or that the scope of a law is restricted to poisons as that term is commonly used, it is becoming customary to refer to pest control chemicals as pesticides.

As the protection afforded by the federal law concerns only materials shipped in interstate commerce, state laws are necessary to provide adequate protection of users of economic poisons shipped solely within a state, and to provide cooperative enforcement of the Federal law. Prior to the second World War, many of the state pesticide laws followed the general pattern set by the Federal Insecticide Act of 1910 and many of them pertained only to a limited number of pest control chemicals. With the advent of DDT, and the development and widespread use of other new synthetic organic pesticides, the importance of adequate labeling and control of injurious materials has been reflected by the changes in state laws. At the request of the National Association of Commissioners, Secretaries, and Directors of Agriculture, the Council of State Governments developed a proposed state insecticide, fungicide and rodenticide act. This was drafted for the convenience of states that might wish to consider legislation and to provide a guide so there would be some uniformity in the legislation. When state laws and regulations covering insecticides and other economic poisons vary greatly from state to state, it is difficult for a manufacturer to prepare a label that will meet both Federal and state requirements. If different labels are required for different jurisdictions, there is an added cost in doing business, with the resultant increase in cost to the purchaser.

The uniform state act has been adopted by thirteen states. There are nine states with no economic poisons law and three others with such limited coverage that they might be considered to be in the class with those that have none. This leaves twenty-three states with various laws, some of which are more inclusive than the uniform act and others that are similar to the old Federal Insecticide Act of 1910 and will need to have their scope enlarged to cover modern materials.

Most of the state laws, as well as the federal law, require registration of each economic poison before it is offered for sale. The purpose of registration is to assure that economic poisons will be of value for the purpose intended and that untried products or worthless products will not be sold to the public. A copy of

each proposed label must be submitted with the application for registration so that the enforcement agency can determine if it provides adequate information including the name of the product, statement of ingredients, pests to be controlled, directions for use, precautions to be taken in its use including poison label and first-aid treatment if necessary, name and address of the manufacturer, and net contents.

Registration of new pesticides presents one of the most difficult administrative problems. New products are constantly being developed, involving new chemicals, new combinations of chemicals, or new uses for chemicals. Before an economic poison can be accepted for registration, adequate data must be available to demonstrate its effectiveness for the purpose intended, and that the proposed handling and use do not present any intolerable hazard. The necessary data depend somewhat upon the particular type of product involved. The type of information that may be needed to establish the eligibility of the product for general sale is suggested by that necessary to complete a proper label.

Formerly new economic poisons were developed gradually. Several years usually elapsed between laboratory development of a new product and commercial sale. This permitted accumulation of data concerning effects of yearly changes due to weather factors and repeated applications. Now farmers and pesticide salesmen watch with a great deal of interest the experimental work that is being carried on. Anything that shows promise is immediately in great demand even though there is inadequate information concerning the material, and serious injury may occur if it is not handled with proper precautions and at the correct dosages.

The effectiveness of a material for control of a pest is only one of the problems involved in its potential usefulness. Some effective pesticides cannot be used or are limited in use because they have some detrimental characteristic. For example, benzene hexachloride may impart a musty flavor to treated crops and to root crops subsequently grown in the same soil. In some cases the off-flavor was not evident until several months after the food crop was canned or otherwise processed. Some pesticides cannot be applied to forage crops because they may injure the cattle that eat it or contaminate the milk of dairy cattle. Some pesticides cannot be applied to certain crops in blossom because they destroy honeybees necessary for pollination. Some pesticides cannot be applied to certain crops because the deleterious spray residue cannot be removed satisfactorily. A new pesticide becomes of value only after its proper scope of use has been determined and its limitations have been evaluated. Full cooperation between entomologists and other research workers with toxicologists, chemists, and food processors is essential to secure information on these other factors which may ultimately determine the usefulness of the materials.

The economic poisons control official relies upon data furnished by entomologists and other specialists to serve as basis for developing rules for adequate labeling of new materials. To be useful, a pest control material must not only kill pests, but also do it without injuring the distributor or his neighbors or their property.

ALLEN B. LEMMON
CHIEF, BUREAU OF CHEMISTRY
California State Dept. of Agr.
June 29, 1951

DR. JOHN T. CREIGHTON TO THAILAND

Dr. Creighton of the University of Florida has accepted an invitation from the Economic Cooperation Administration to join the special and technical mission to Thailand. He will serve as head of the entomology section in agriculture and is charged with the responsibility of establishing a college, in the vicinity of Bangkok, similar to a land-grant college in the United States. In order to build up a reference library he would like to receive publications dealing with insects, nematodes, mites, rodents, etc., and their control. They should be addressed as follows:

JOHN T. CREIGHTON
Special & Technical Mission to Thailand
Economic Cooperation Administration
c/o U. S. Embassy
Bangkok, Thailand

BOOK REVIEWS

INSECTS AND HYGIENE, by James R. Busvine. Methuen & Co., Ltd., London 482 pp., 58 illustrations. 1951. 30 s.

The author of this discourse on the biology and control of insect pests of medical and domestic importance in Britain is a medical entomologist of the London School of Hygiene and Tropical Medicine. The first four chapters show how insects may affect the health of man and emphasize how insects have evolved as predominant land animals. There are excellent discussions of the physiology and ecology of insects. The section on morphology is somewhat sketchy. Books comparable to this one usually devote more space to an explanation of insect mouthparts. The historical notes are good, but Americans will regret the omission of any reference to the discoveries of Smith and Kilbourne on the transmission of Texas cattle fever by a tick. There is a section entitled Disgust, and several pathological cases are cited to show that psychiatric help is needed by persons suffering from delusions of annoying insects. Most medical entomologists have had some experience with similar cases of entomophobia.

Preceding the chapters on specific pests there are sections on organization of control measures, mechanical and physical control, and insecticides. The more than adequate review of insecticides—theory and practice—is a most valuable feature of the book. There is also a chemical appendix which contains suggestions for quantitative estimation of various poisons and lists many insecticidal substances, including those with commercial names, giving data on the chemical nature of them.

Detailed discussions of the biology and control of arthropods affecting the health and comfort of man are grouped in nine chapters as follows: houseflies and blowflies, blood-sucking flies, parasites (bugs, lice, fleas, mites), pests of foodstuffs, pests in waste products, clothes moths and carpet beetles, woodboring beetles, stinging and biting insects, and nuisances. This part of the book is an extremely well-balanced, thorough and readable treatment of the diverse pests. In the biological appendix are keys for the identification of domestic insect pests. The keys can be used by those with little or no entomological training.

On the whole, medically important insect problems in Britain are not so serious as those in North America. There appears to be no disease transmission by arthropods at the present time even though houseflies are believed to be involved in the transmission of enteric diseases. Malaria, encephalitis, and rickettsial diseases are absent; among other unknowns are dog ticks and termites; the need for fly and mosquito control is not so critical as in warmer countries. Application of insecticides by airplane is not mentioned. The more important problems are bedbugs, lice, and scabies.

In a comprehensive book like this, bibliographical work is enormous, and it is inevitable that certain omissions occur. There are two missing references that might be mentioned, namely, Bates' Natural History of Mosquitoes and James' publication on myiasis. The line drawings are well executed, but a few more might have been added along with some photographs—for example power sprayers.

Dr. Busvine has succeeded admirably in organizing and presenting a large quantity of information of value to health officers, sanitarians, pest control operators, and agricultural and industrial workers dealing with stored products. Applied entomologists throughout the world will frequently refer to this useful contribution to their science.

WILLIAM E. BICKLEY

Pesticide Handbook. Donald E. H. Frear, Pp. 158. Commercial Printing Co., Inc., State College, Pa. Price, $1.00.

Pesticide Handbook is a continuation and expansion of *Pest Control Materials* published in 1949 and revised in 1950.

Subheadings in the book include Insecticides, Fungicides, Herbicides, Rodentocides, Adjuvants, Diluents and Application Machinery.

Section I lists all the Commercial materials mentioned under the trade names and indicates the active ingredients of each and the use for which each material is sold.

Section II lists the insecticides alphabetically by the names of the chemicals of which they are composed and follows this with lists of fungicides, fungicide-insecticide combinations, herbicides and defoliants, Insecticides-animal dips, baits, concentrates for manufacturing dusts, fumigants, mothproofing materials, paints, repellents, smears (screw-worm), sprays and systemic insecticides. Each of these is identified chemically and furnished with cross-references to other places where it is mentioned.

Equipment for application of the pesticides is listed in a section with suitable cross-references. Pesticide equipment, plant hormones, rodenticides, plant hormones, seed treatments and wood preservatives are each listed separately and identified chemically.

Section III lists the manufacturers of these materials in alphabetical order and gives cross references to the materials manufactured by each and listed previously in the book.

A table which indicates the compatibility of common spray materials with each other is furnished and should add to the value of the book.

When we consider the fact that scarcely more than a decade ago the number of insecticides of established use was small enough so that any economic entomologist had, as a matter of course, knowledge of the fundamental facts about each of them and the same was true of many up to date farmers and fruit growers, county agents and others concerned with insect control problems of the farmer and fruit grower and then contrast that situation with the present where there is an ever-increasing list of insecticides which did not exist in any form at that time and the majority of which are still very imperfectly known to those who must advise prospective users of their insecticidal qualities, their chemistry, their hazards to plants, man and animals, the absolute necessity of information such as is conveniently arranged in the *Handbook* becomes very apparent. Most entomologists do not hesitate to acknowledge their dependence on the insecticide chemists. And no entomologist can safely ignore the facts summarized in the handbook. It is therefore most obvious that Dr. Frear and his associates have performed a real service in starting and continuing this publication. It should also be marketed among county agents and extension specialists who have to do with pest control.

NOTES

CORRECTION

The accompanying figure is the "Figure 1" to which reference was made on page 863 in the paper "Effects of DDT Spray Residues on Larvae of the Tick *Dermacentor variabilis* Say," by D. L. Collins and R. V. Nardy, which appeared in the December 1950 issue of the Journal (Vol. 43:(6) pp. 861–863). This figure was apparently lost or dropped out during the processing of the paper for printing.

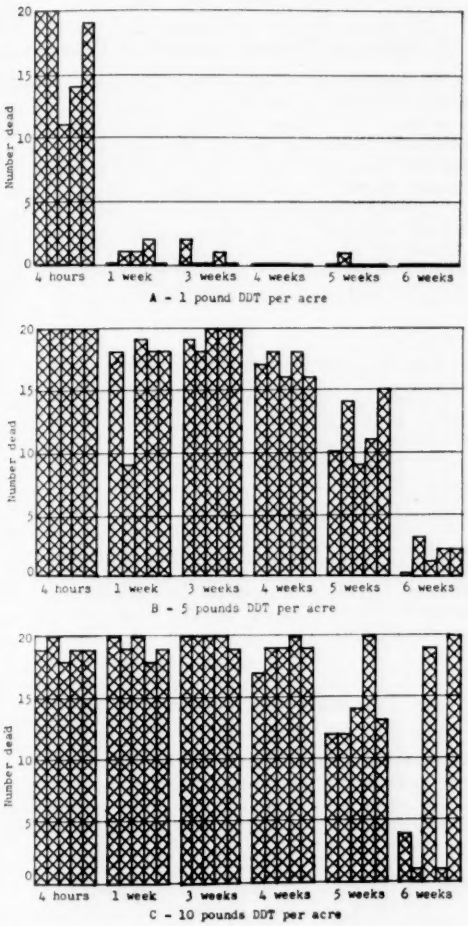

FIG. 1.—Duration of residual effectiveness of 1 pound, 5 pounds and 10 pounds per acre dosages of DDT on larvae of *Dermacentor variabilis*. Each bar represents a replicate of 20 ticks.

THE NATURALIST'S DIRECTORY

The 36th edition of the *Naturalists Directory* has just been published at Salem, Mass., by Herman E. Cassino. This directory was published first in 1878, at Salem, Mass., and has appeared regularly since then, every two or three years. It contains the names and addresses of hundreds of amateur and professional naturalists and their scientific interests. It also includes a list of natural history museums and scientific periodicals. The price is $3.00, postpaid.

NOTICE

"Did you fail to receive your journal? If you did, maybe you are in one of the following categories: February journals that were returned showed the following classifications: (1) 23 were returned for which no change of address had been requested. We got the change from a P.O. pink slip; (2) 12 were returned because the correction, although it had been made in our list, was not made in time for the mailing of the February journal; (3) 2 journals were returned for which we still have no correct address. The plates have been removed in the expectation that we may get a kick and thus get a correct address; (4) 3 were returned that had been sent to individuals who had resigned or who were in arrears and should not have been sent the journal." —Ernest N. Cory, Secretary-Business Manager.

MANUAL OF ENTOMOLOGICAL TESTING METHODS

In 1948, the Entomology Subcommittee of the Chemical-Biological Coordination Center obtained information on insecticide testing from numerous laboratories and the results were distributed to participants. The Subcommittee planned to continue this successful survey.

Recently, after discussions with the American Association of Economic Entomologists and others, the Subcommittee believed that a book on testing methods in entomology would be more useful and, in April 1951, Dr. Harold H. Shepard, U. S. Department of Agriculture, was designated editor.

The book will include toxicological and screening methods used by entomologists in this and other countries and will contain descriptions of methods detailed enough to permit them to be duplicated. It will be published by the National Research Council and sold at cost.

The Subcommittee will provide forms for those who wish to participate in this project by furnishing descriptions of the test methods which they use. Send request for forms to—

Dr. RAIMON L. BEARD, *Chairman*
Entomology Subcommittee
Chemical-Biological Coordination Center
National Research Council
2101 Constitution Avenue
Washington 25, D. C.

PAUL A. BERRY TO GO TO EL SALVADOR

Mr. Paul A. Berry has gone to El Salvador under the direction of the Office of Foreign Agricultural Relations where he will be stationed at the Experiment Station operated in that country by the United States and El Salvador.

Mr. Berry's fourteen years of experience in foreign countries as a representative of the Bureau of Entomology and Plant Quarantine principally interest in the study of parasites of have, may have, value in control of foreign insects established in this country should make his presence and work in El Salvador of great mutual benefit.

UNIVERSITY OF MICHIGAN LIBRARIES

MINNESOTA ENTOMOLOGIST TO INDONESIA

Donald R. Johnson of St. Paul, assistant state entomologist, reported June 18, 1951 in Washington, D. C., for three weeks training preparatory to an assignment in Indonesia to advise workers fighting malaria. Johnson has served as an entomologist with the Minnesota Department of Agriculture, Dairy and Food the past three years, with headquarters on the St. Paul campus of the University of Minnesota. He holds a master's degree in entomology from the University.

In Indonesia, with headquarters at Djakarta, Java, he will advise native personnel in three malaria research institutes and a large number of local health organizations. Rates of malaria run as high as 70 per cent in Indonesia.

Johnson's new assignment, for which he has been granted a leave of absence by the Minnesota Department of Agriculture, will be part of a project carried on jointly by the U. S. Public Health Service and ECA. He was for two years during World War II an officer in charge of a Navy unit doing malaria control work in New Guinea and the Philippines. His wife and two children will join him in Indonesia later.

A.A.E.E. REFERENCE STANDARDS

With the cooperation of the various members of the insecticide industry, the American Association of Economic Entomologists, Section on Insecticides has undertaken the sponsorship of insecticide reference standards. These standards are chemical standards of known purity and are intended chiefly for bioassays of insecticides; however, they are also suitable for use as standards for chemical assays. It is felt that these standards will be useful in collaborative insecticides research studies. The following A.A.E.E. REFERENCE STANDARDS will be available on April 1, 1951:

DDT, technical grade
Methoxychlor, technical grade
Lindane
Toxaphene
Tetraethyl pyrophosphate, 40%
Parathion, technical grade
Chlordane, technical grade

There will be a charge of $1.00 per standard. Order must be accompanied by remittance. All shipments will be made via express collect. Send orders to the following distributing agency: Wisconsin Alumni Research Foundation, Insecticide Testing Laboratory, Madison 1, Wisconsin.

CHANGES IN BEPQ

The Division of Plant Disease Control has been abolished and the direction of the white pine blister rust and the barberry eradication programs of this division has been assigned to the regional offices. Dr. J. F. Martin will function as staff assistant in the office of the chief.

The Division of Domestic Plant Quarantine has also been abolished. Transit inspection work has been assigned to the Division of Plant Quarantines (formerly Foreign Plant Quarantines). Sweetpotato weevil, white-fringed beetle, phony peach and the peach mosaic disease programs have been assigned to the regional office at Gulfport, Mississippi. Mr. R. A. Roberts formerly acting in charge of the Division of Plant Quarantines has been temporarily detailed as assistant to the regional director of the Southeastern Region.

EUROPEAN ENTOMOLOGIST AT WARD'S

The department of entomology at Ward's Natural Science Establishment, Inc., of Rochester, N. Y., is now headed by Charles S. Papp a graduate, in 1943, of the University of Szeged, Hungary and a well-known coleopterist. His collection of Coleoptera included 64,000 classified specimens before it was destroyed by bombing. Less than two weeks before he was scheduled to be examined for his doctor's degree, the advance of the Russian army forced him to go to Germany with his family. His six years in that defeated country are best forgotten.

DR. RALPH B. SWAIN TO NICARAGUA

On July 15, 1951 Dr. Swain left this country for a Point Four assignment in Managua, Nicaragua where he will assist the Government of Nicaragua in the control of insects affecting food and fiber crops. His assignment is a part of this country's Point Four program of sharing its technical abilities with other countries. Dr. Swain joined the BEPQ in 1938 as supervisor of a Mormon cricket program in 8 northern states. Since 1945 he has been attached to the Inspection Station at the Hoboken, N. J., point of entry. In Nicaragua Dr. Swain will join 3 other specialists.

WILLIAM CRAWFORD GORGAS

The unveiling of the bust of William Crawford Gorgas in the Hall of Fame for Great Americans on the campus of New York University on May 24, 1951, was a notable occasion in recognition of accomplishments to a large extent in the field of applied entomology.

Dr. William H. Welch in conferring on General Gorgas the degree of LL.D. stated in part:

". . . He it was who, by application of the discoveries of Major Reed and his colleagues of the Army Yellow Fever Commission, was mainly instrumental in freeing Cuba of yellow fever, and he it is who, in spite of obstacles and embarrassment, has made the construction of the Isthmian Canal possible without serious loss of life or incapacity from disease— . . . ."

Proceedings of the Thirty-Fifth Annual Meeting of the Pacific Branch American Association of Economic Entomologists

Seattle, Washington, June 19, 20 and 21, 1951

The thirty-fifth annual meeting of the Pacific Branch was held in Seattle, Washington, June 19, 20 and 21, 1951. The officers during the meeting were: Ed. H. Littooy, *Chairman;* Glenn E. Carman, *Vice-Chairman;* and Leslie M. Smith, *Secretary-Treasurer.* The chairmen of the various committees were: L. G. Gentner, *Program;* R. S. Braucher, *Arrangements;* Mrs. D. J. Chamberlin, Jr., *Arrangements for ladies;* D. J. Crowley, *Registration;* Ed Coe, *Operations;* G. F. MacLeod, *Press;* L. D. Anderson, *Resolution 7;* W. M. Hoskins, *Resolution 5;* W. W. Middlekauff, *Membership;* S. W. Strew, *Resolutions,* W. Ebeling, *Auditing,* and L. Childs, *Nominations.* Acting chairmen at various times during the meeting were: E. H. Littooy, G. E. Carman, L. G. Gentner, and M. H. Hatch.

The assembled entomologists were welcomed in the opening address by Dr. Raymond B. Allen, President of the University of Washington. President Roy Campbell, of the American Association of Economic Entomologists, reported on the national meeting held in Denver in December, and reported the results of the poll on amalgamation of the American Association of Economic Entomologists and the Entomological Society of America. Dr. W. A. Ross, President of the Entomological Society of Canada delivered greetings from that Society, which was born last November, and from the Entomological Society of Ontario which was born 88 years ago. Dr. G. J. Spencer, President of the Entomological Society of British Columbia delivered an interesting invitational paper on Entomology in British Columbia. Dr. Avery S. Hoyt, Chief of the Bureau of Entomology and Plant Quarantine, spoke briefly on the reorganization of the Bureau.

The formal program of the meeting contained 32 submitted papers, 8 invitational papers, 2 panel discussions, and one evening symposium on extension. The invitational speakers were: G. F. MacLeod, Chemicals for Western Agriculture in a Defense Economy; A. W. Lindquist, Radioactive Materials in Entomological Research; Walter Carter, Recent Developments in Oriental Fruit Fly Research (illustrated by an excellent moving picture); R. L. Metcalf, Systemic Insecticides; Ernest Hart, Entomology and Production Join Hands for Defense; J. H. Pepper, Insect Physiology in Practical Applications; and J. C. Chamberlin on Deposit of Sprays from Airplanes.

A panel discussion of plant poisoning by agricultural chemicals in the soil was led by M. C. Lane and the panel consisted of H. E. Morrison, E. C. Klostermeyer, W. H. Lange, L. L. Stitt, and K. M. King. Another panel discussion was held on recent developments in spider mite control. This discussion was led by S. C. Dorman and the panel consisted of E. J. Newcomer, James Marshall, H. T. Reynolds, Leroy Childs, and W. J. O'Neill. The discussion of extension entomology was led by J. N. Roney.

At a preliminary business session Chairman Ed Littooy reported the results of the ballot on the proposed constitution. All votes were in favor of the new constitution except one. The constitution is therefore adopted. Among other things it defines the territory of this branch and changes the name to Pacific Branch by deleting the word Slope.

Chairman Littooy reported the results of a mail ballot on time of meeting. June was favored by a large plurality over any other month.

Secretary L. M. Smith reported that the Pacific Branch added 94 new members during the past year.

Professor H. S. Telford suggested that a means be found to bring employers and job-seekers together. After considerable discussion from the floor, the following motion was made by W. J. Francis: The incoming chairman shall appoint a committee of three men and the Secretary to study methods of establishing an employment system, and to study particularly the methods used by other organizations such as the American Chemical Society. This motion was seconded and passed unanimously.

The secretary-treasurer presented the following report:

Treasurer's Report

	Credits	*Debits*
Balance in treasury, June 13, 1950	$407.65	
Registration fees, 1950 meeting, and miscellaneous income	330.72	
Mimeographing constitution		7.23
Printing letterheads		15.77
Postcards		13.00
Stamps		1.00
Addressing cards		10.00
Printing announcements, etc.		47.33
Stamped envelopes		25.44
Blank cards		1.50
Addressing envelopes and copying mailing list		25.00
Stamped envelopes		27.24
Telegrams		5.88
Addressing and mailing		20.00
Stamped envelopes		21.80
Typing program and addressing envelopes		20.00
Printing programs		128.75
	$738.37	369.94
Balance in treasury, June 18, 1951		368.43
	$738.37	$738.37

At the final business meeting the report of the auditing committee was given as follows:

Report of the Auditing Committee

We have examined the accounts of the Treasurer and find them to be correct.

Leo R. Gardner Walter Ebeling, *Chairman*
W. J. O'Neill

The treasurer's and auditing reports were accepted by the members.

A. F. Kirkpatrick reported the results of a mail ballot on methods of conducting meetings and presentation of papers. This questionnaire contained 17 items and the results are embodied in resolution 4, see below.

Under the newly adopted constitution, government of the Branch is vested in an Executive Committee, composed in part of three members elected from the membership. Chairman Littooy called for nominations for the Executive Committee from the floor. The following were nominated and unanimously elected.

Walter Carter J. C. Chamberlin
W. Harry Lange

Chairman Littooy called attention to the fact that the Committee on Advanced Meeting Schedule had selected Santa Barbara, California for the meeting of the Pacific Branch in 1952, and this stands as the tentative meeting place, subject to change by the Executive Committee if suitable facilities are not available.

The chairman called for the following reports:

REPORT OF THE COMMITTEE ON RESOLUTIONS

Resolution No. 1

WHEREAS, the members of the Pacific Branch of the American Association of Economic Entomologists, in attendance at the thirty-fifth annual meeting of this branch held in Seattle, Washington on June 19, 20 and 21, 1951, have enjoyed a worthwhile and successful meeting and are deeply grateful to various agencies and organizations which have made this possible; therefore, be it resolved that thanks be extended to the various committees having to do with the organization and conduct of this meeting and especially

To L. G. Gentner, Chairman, and the other members of the Program Committee for their successful efforts in arranging the very interesting and valuable program.

To R. S. Braucher, Chairman, and the other members of the Committee on Arrangements for their careful and thorough planning.

To the industrial and Commercial Concerns for their generous financial aid in providing refreshments, the cruise on the S. S. *Sightseer* and transportation for all events.

To Committee on Arrangements for Ladies consisting of Mesdames Ed H. Littooy, R. S. Braucher, D. J. Chamberlin, Jr., L. L. Gable and W. J. F. Francis.

To Mrs. Walter Ebeling for thoughtfully providing orchids for members and guests.

To Ed. H. Littooy, Chairman, Glenn C. Carman, Vice-Chairman and Leslie M. Smith, Secretary-Treasurer for their untiring efforts in making possible this highly successful meeting.

Resolution No. 2

WHEREAS, the membership of the Pacific Branch of the American Association of Economic Entomologists highly appreciated the Address of Welcome from President Raymond B. Allen of the University of Washington; therefore, be it resolved that the Secretary be instructed to express the sincere appreciation of the membership to Dr. Allen for his words of welcome.

Resolution No. 3

WHEREAS, the cooperation of the Manager, Mr. A. Hough, and employees of the Edmond Meany Hotel has been an important factor in the success of this annual meeting; therefore, be it resolved that the Secretary shall suitably convey to the Edmond Meany Hotel an expression of appreciation from the Pacific Branch, American Association of Economic Entomologists for assistance in arranging for this most satisfactory and enjoyable 35th annual meeting.

Resolution No. 4

WHEREAS, a committee on conducting meetings under the chairmanship of L. D. Anderson, has submitted the results of their mail ballot; therefore, be it resolved that the results of this vote shall serve as a guide to future program committees and presiding chairmen in arranging and conducting future meetings.

Resolution No. 5

WHEREAS, the Delaney Committee has tentatively proposed that legislation be enacted amending the Food, Drug and Cosmetic Act of 1938 to withdraw the licensing for purposes of interstate commerce of pest control chemicals from the Insecticide Division, USDA, as provided by the Insecticide, Fungicide and Rodenticide Act of 1947, and

WHEREAS, this proposed change would jeopardize the welfare of agriculture and hence that of the whole nation, by removing the licensing power from the hands of agriculturalists who understand the practical problems for which pest control chemicals are used, and would give it to those who are remote from agriculture and unqualified to exercise such power, and

WHEREAS, the existing laws for the regulation of trade in pest control chemicals and uses thereof are now administrated effectively for the mutual benefit of farmers, manufacturers, food processors and the general public including the public health and changes would increase the cost and lower the quality of foodstuffs and,

WHEREAS, complete testing of a chemical in all of its necessary formulations could only be done at immense expense and after so much delay that advances in pest control would become well-nigh impossible, and

WHEREAS, attempts by a few witnesses before the Committee to represent the use of pest control chemicals as a menace to public health have not been founded upon fact, and

WHEREAS, the present arrangement whereby responsibility for the proper use of chemicals in agriculture is placed jointly upon the USDA and the FDA has resulted in this nation enjoying the most abundant and highest quality food in the world, now

Therefore, be it resolved that the Pacific Branch of the AAEE at its thirty-fifth annual meeting at Seattle, Washington, on June 21, 1951, hereby urges the chairman and members of the Delaney Committee, collectively and individually, to avoid all action which would impose further burdens upon agriculture or weaken the existing harmonious operation of the licensing and inspection system.

Since entomologists direct the application of most chemicals used in pest control, they cannot and should not escape responsibility for both the immediate and long range effects of these materials. Therefore, this Conference expresses its active interest in the expansion of facilities for toxicological testing, residue analysis, food quality control, the development of non-hazardous pesticides and the utmost use of other methods for pest control. Since toxicological testing is necessarily slow and expensive, it is suggested that administrative officers of schools of veterinary medicine be appraised of the situation since their staffs and facilities are uniquely adapted for such work.

The secretary is hereby directed to send copies of this resolution to

The Secretary of the Department of Agriculture

The Director of the Federal Security Agency

The Chief of the Bureau of Entomology and Plant Quarantine

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The Congressmen and Senators from all western states

The Directors of State Departments of Agriculture of all western states and other interested persons as he may decide.

Resolution No. 6

WHEREAS, Dr. W. M. Hoskins, Chairman of the Committee on Resolution No. 5 adopted at our thirty-fourth annual meeting, has requested that this Committee be continued and expanded; therefore, be it resolved that the incoming Chairman confer with Dr. Hoskins and appoint the necessary additional committee members.

Respectfully submitted,

FRED DEAN STANLEY STREW, *Chairman,*
DAVID BRANNON *Resolutions Committee*

These resolutions were unanimously accepted by the membership.

REPORT OF THE NOMINATIONS COMMITTEE

The Nominations Committee offers the following names to fill offices of the Pacific Branch for the year 1951–52:

Chairman: GLEN E. CARMAN
Vice-Chairman: STANLEY F. BAILEY
Secretary-Treasurer, for a three year term:
LESLIE M. SMITH

Nominations Committee

J. HOLLOWAY LEROY CHILDS, *Chairman*
M. C. SWINGLE L. A. CARRUTH

The report of the nominating committee was accepted by the membership, no further nominations were made from the floor, and the above nominees were unanimously elected. This concluded the business session.

This meeting was one of the most satisfactory meetings ever held by this Branch. The weather was excellent, and the facilities in Seattle were very convenient. A unique feature was the annual dinner, served aboard a steamship which was chartered by the Branch. This vessel carried the members and their families on a cruise of Puget Sound and Lake Washington, for five hours on Wednesday evening. Two excellent luncheons were arranged for the ladies at the Seattle Yacht Club and the Seattle Tennis Club.

MEMBERS AND GUESTS REGISTERED

Allen, Frank D.
Allen, Paul B.
Allen, Raymond B.
Alexander, C. C.
Anderson, L. E.
Anthon, Edward W.
Armitage, H. M.
Ash, Al
Atkins, Larry

Ball, W. E.
Barnnon, Roy R.
Bashor, E. F.
Blanchett, P. J.
Bodine, E. W.
Boissonou, C. J.
Bonn, A. E.
Brannon, Dave
Braucher, R. S.
Bronson, Art
Brouillette, Marvin
Brown, Frank A.
Brunn, Lynn K.
Burden, Ivor R.
Burns, Frank A.
Burnside, W. H.
Bussart, J. Everett

Campbell, Roy E.
Carlson, Elmer C.
Carman, Glenn E.
Carter, George F.
Carter, Walter
Chamberlin, J. C.
Childs, Leroy
Clausen, C. P.
Clem, B. L.
Coe, Ed. H.
Coffin, O. T.
Coffman, George W.
Colburn, F. C.
Compton, C. C.
Couch, John N.
Crail, William F.
Crowell, H. H.
Crowley, D. J.

Darley, Merrill M.
Davis, John E.
Dean, D. W.
Dean, Fred P.
Degginger, Edward
Denning, D. G.
Dolman, C. D.
Dorman, S. C.
Douglass, J. R.
Doyle, E. T.

Eagleson, Craig
Ebeling, Walter
Eichmann, R. D.
Eide, Paul M.
Evans, A. W.
Ewart, W. H.

Finney, Glenn L.
Fisher, Robert A.
Flebut, A. J.
Fleschner, C. A.
Francies, Merritt C.
Francis, W. J. F.
Frick, Kenneth E.

Gardner, Leo R.
Gentner, Louis G.
Graves, Chester E.

Hamsher, C. A.
Hantsbarger, Wm. M.
Hardman, Newt
Hatch, Melville
Henriksen, Lars E.
Hitchcock, O. B.
Hoard, Bill
Hoyt, A. S.

James, Cosby C.
Jarnagin, W. M.
Jones, S. C.
Jonson, Wm. L.

Kagy, J. F.
Keating, D. J.
King, Kenneth M.
Kipple, Charles A.
Kirkpatrick, A. F.
Klostermeyer, E. C.

Lane, Merton C.
Lange, W. Harry
Latta, Randall
Lindgren, David L.
Lindquist, A. W.
Littooy, Ed.
Lloyd, A. T.
Loeffler, Erwin S.
Lund, Roy H.
Mack, Bud
MacLeod, G. F.
Malley, Nuri
Magner, J. M.
Marshall, Jas.
Matson, Harold J.
McCauley, W. E.
McNelly, L. B.
Menke, Herman
Metcalf, R. L.
Miller, Roy E.
Milliman, Loren H.
Mitchell, A. A.
MontFort, K. W.
Morrison, H. E.

Newcomer, E. J.

O'Neill, W. J.
Ortega, Jack
Otis, Chester

Pellett, M. F.
Pepper, J. H.
Peters, Richard F.
Pullen, Eddie

Rapp, Frank
Reeks, L. D., Jr.
Reynolds, H. T.
Roney, James N.
Ross, W. A.
Roullard, Fred P.
Rouse, Glenn F.

Scott, Roger
Siddall, Cameron
Sime, Keith
Smith, Harold K.
Smith, Leslie M.
Starker, Chuck
Steinen, Otto P.
Stitt, Loyd L.
Strew, Stanley W.
Sturges, K. Lee
Swain, Al
Swift, J. E.
Swingle, M. C.

Telford, H. S.
Terriere, L. C.
Thrailkill, Byrne
Turner, J. H.

Underhill, R. W.

Vogel, M. A.

Wade, Kenneth
Wampler, Elvin L.
Watwood, Robert
Wegenek, Edward G.
Weldon, Geo. H.
Westgate, W. A.
Wolf, E. J.
Wolfe, Homer R

Yates, Willard W.
York, C. H.
Yust, Harold R.

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